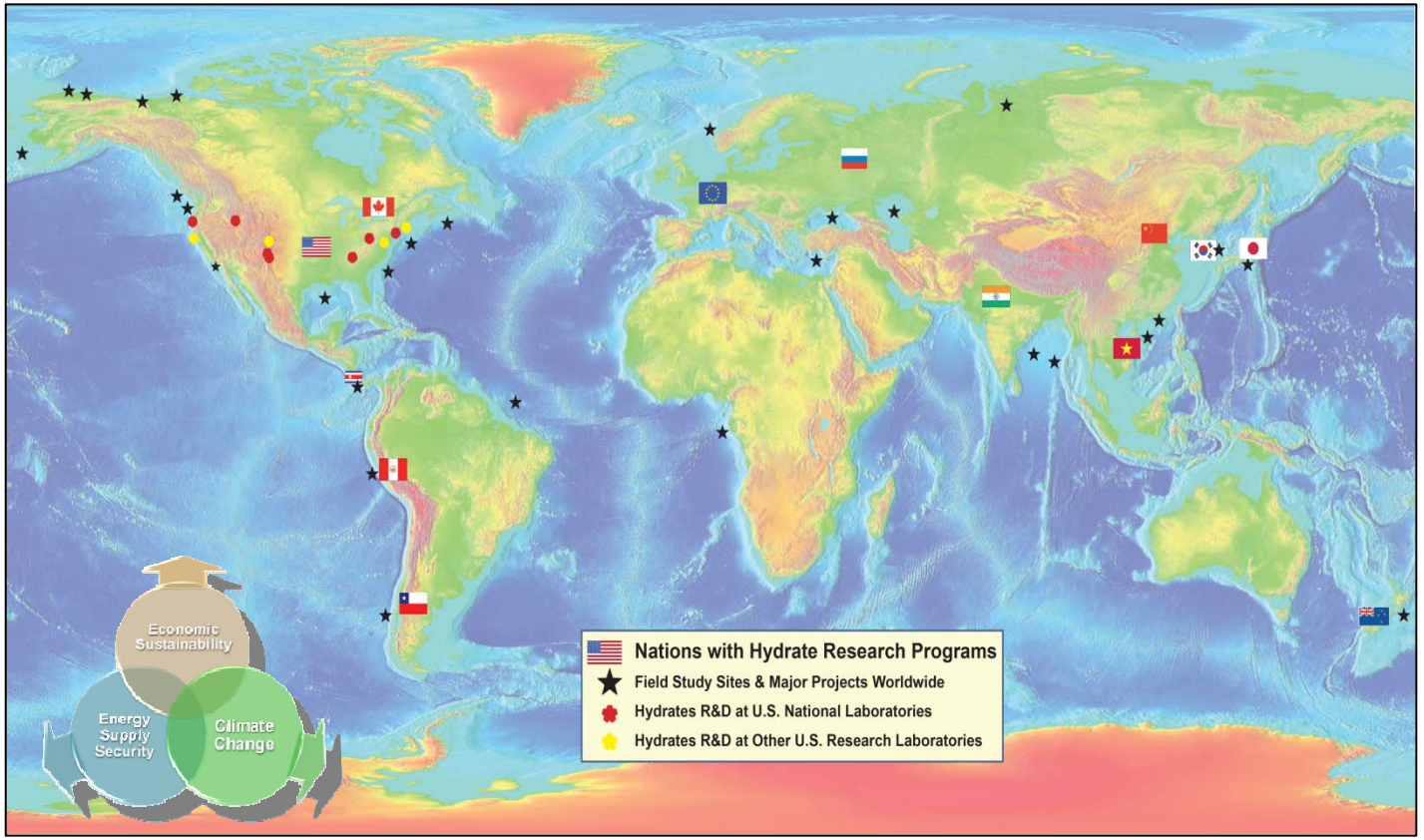
NATIONAL ENERGY TECHNOLOGY LABORATORY



The Global Pursuit for Methane Hydrates:
Advances in Exploration and Present Hurdles

Kelly Rose – Methane Hydrates Field Studies Research Lead

Coring activities at Mount Elbert gas hydrate stratigraphic test well, Milne Point, Alaska, February, 2007

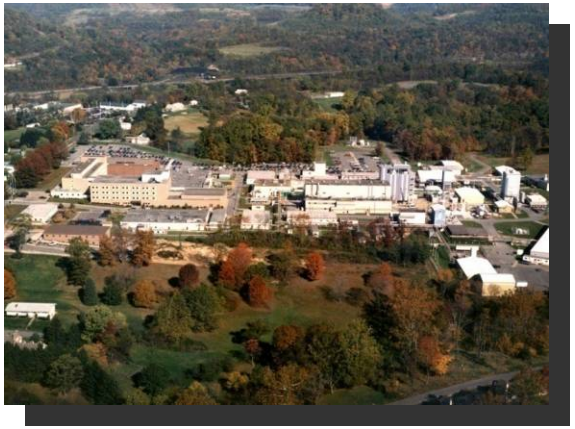
Presentation Outline

- **The National Energy Technology Lab**
- Overview of naturally-occurring gas hydrates
  - What are gas hydrates
  - Where do they occur
  - Why is there so much interest…
- The National Methane Hydrate R&D Program
- Recent major international gas hydrates field exploration efforts
- Exploration challenges and the Program's efforts to address these key issues
  - Basic Science: Where, why, how?
  - Resources: How much?
  - G&G: Can we find them?
  - Engineering: Can we produce them?

National Energy Technology Laboratory

- DOE's national lab dedicated to fossil energy
  - Fossil fuels provide 85% of U.S. energy supply
- One lab, three research campuses
- 1,200 Federal and support-contractor employees
- Research encompasses fundamental science through technology demonstration

Pennsylvania



West Virginia

Oregon

Burning methane hydrate samples recovered during Korea's UBGH-01 Expedition 2007 (photo - KIGAM)

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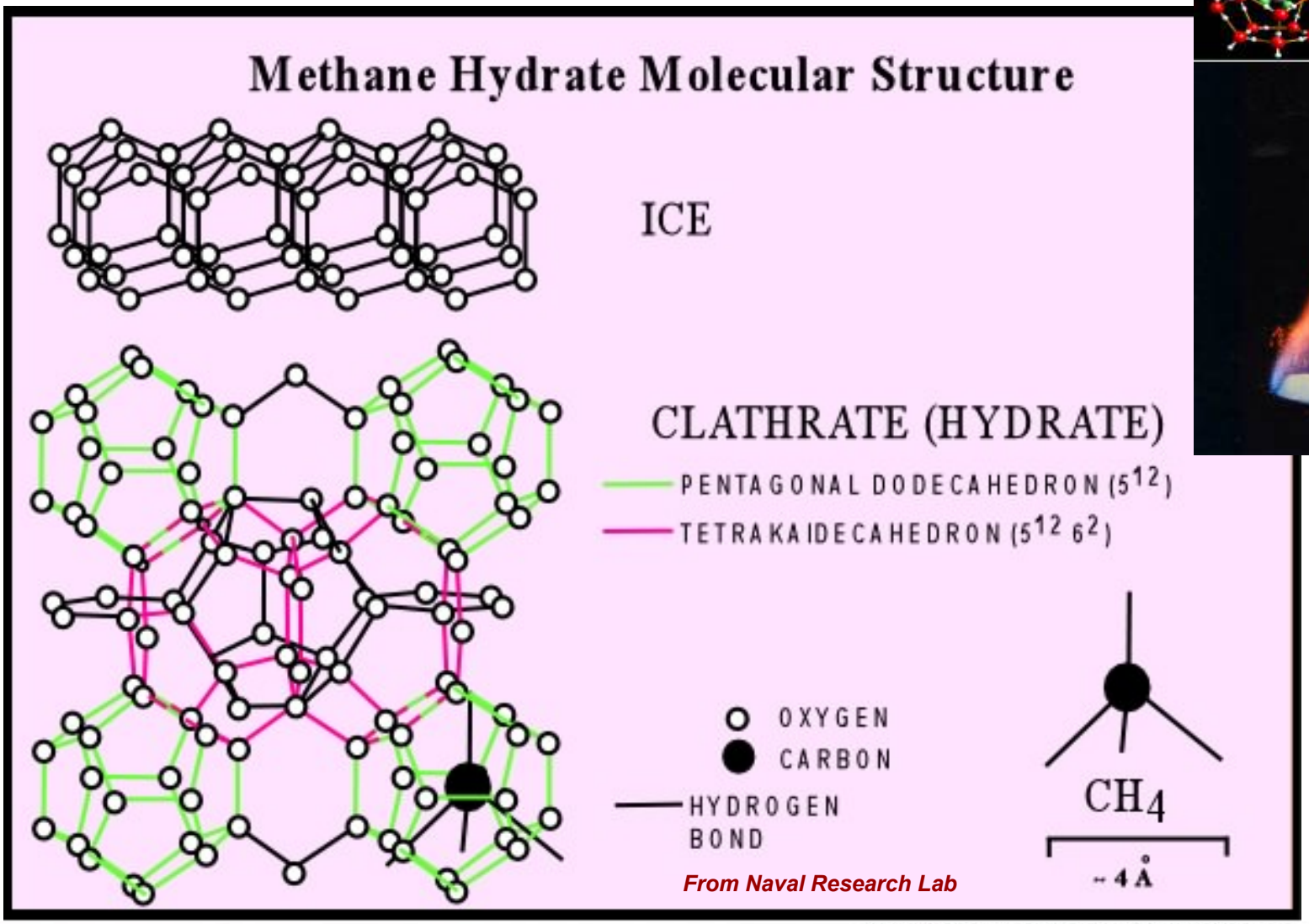
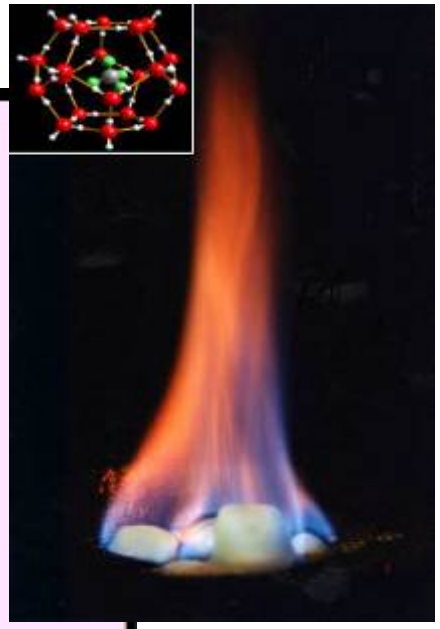
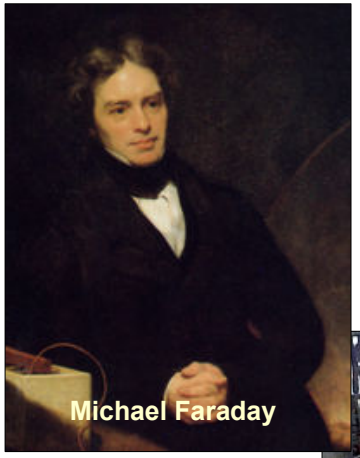
What are gas hydrates?



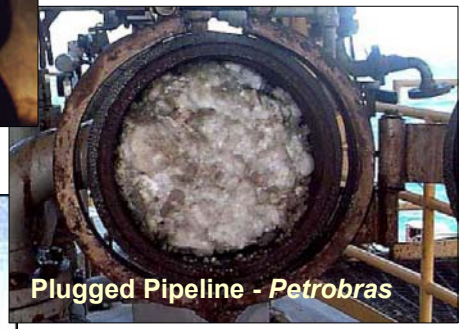
From Naval Research Lab



Natural Gas Hydrates
Setting the Stage


Michael Faraday

- **1800s:** Michael Faraday creates hydrates of Chlorine in the lab
- **1930s:** Hydrates of methane gas found plugging natural gas pipelines
- **1960s:** Strange production responses noted in Siberian gas fields – initial tests in Alaska
- **1982:** Massive sample recovered off Guatemala
- **1982-1992:** USDOE-USGS: document extent of MH worldwide.
- **1995:** USGS reports 320,000 tcf gas in place in US EEZ. Japan starts massive 15-year program
- **2000:** Methane Hydrate R&D Act passed – authorized for five years, calls for broad, interagency investigation of hydrate issues

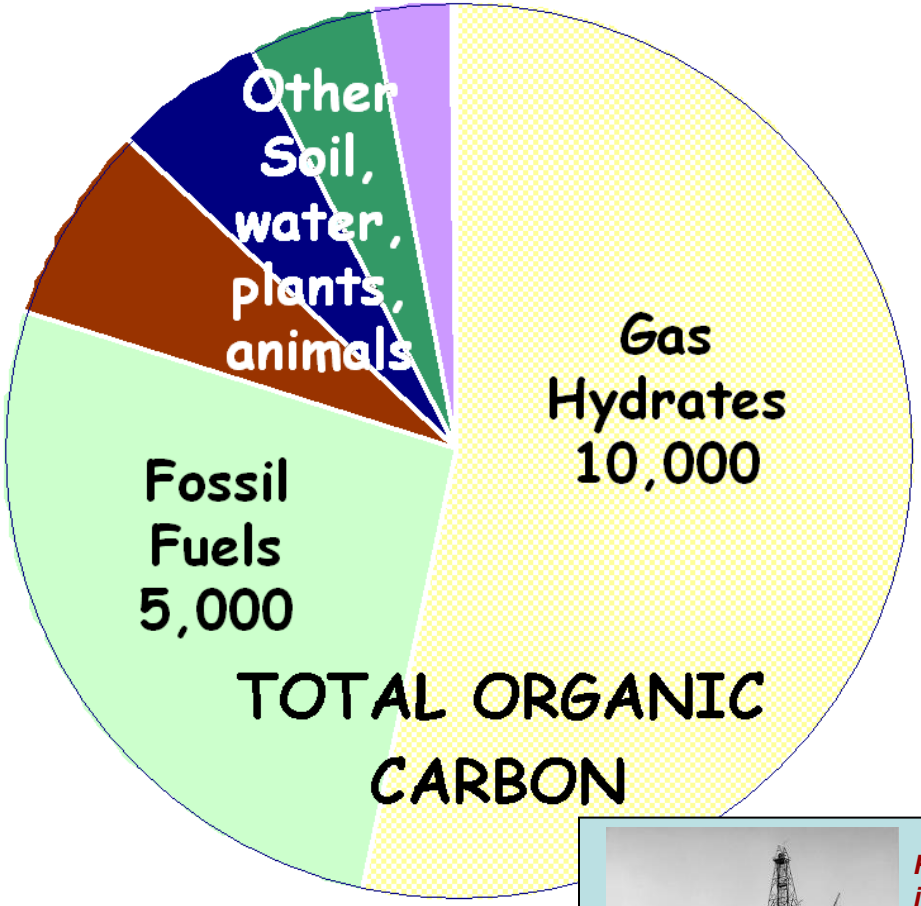

Plugged Pipeline - *Petrobras*

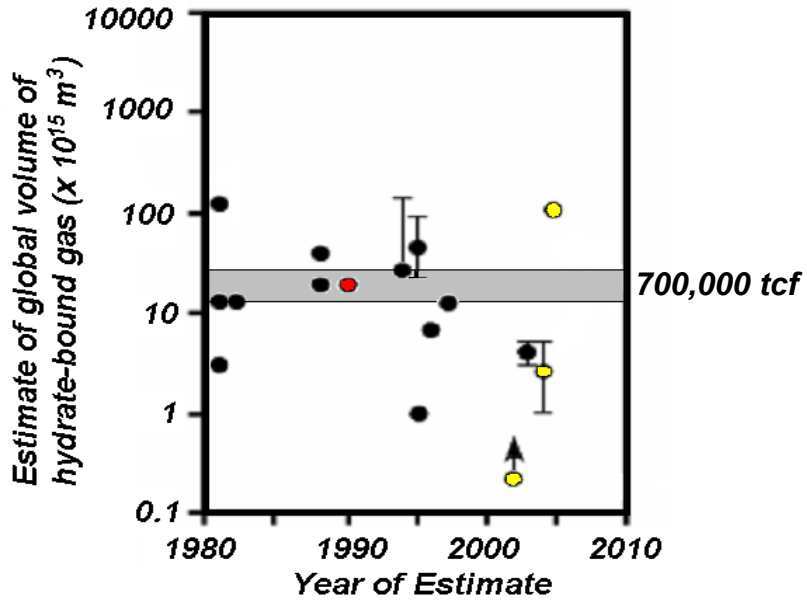

Glomar Challenger; Offshore Guatemala, 1982


Sample retrieved at Mallik Site NW Canadian Arctic, 1998

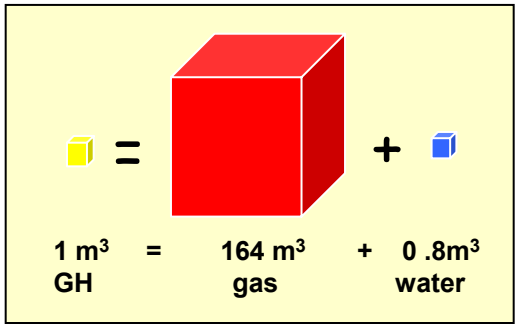
Gas Hydrate

An enormous global storehouse of Organic Carbon



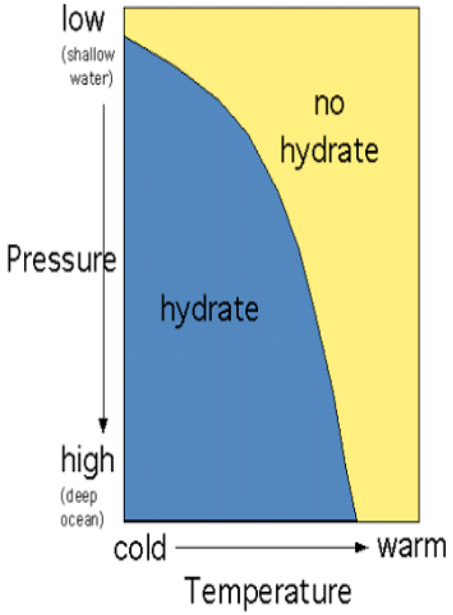


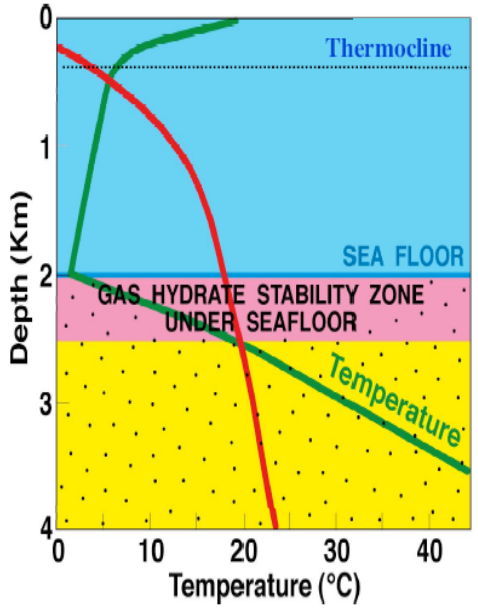
First seen in nature by the Glomar Challenger in 1982

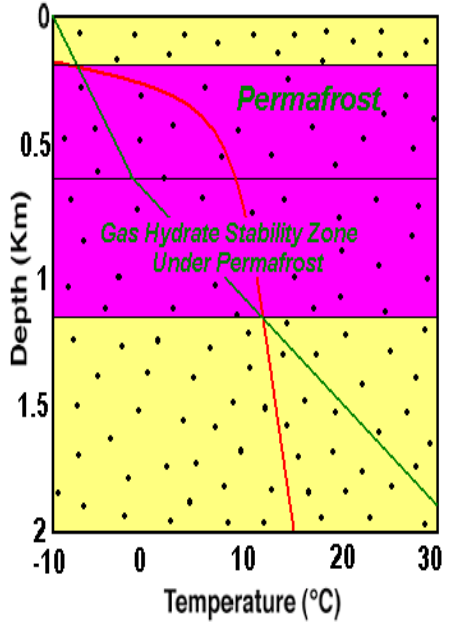


Controls on Gas Hydrate Occurrence
Gas Hydrate Petroleum System

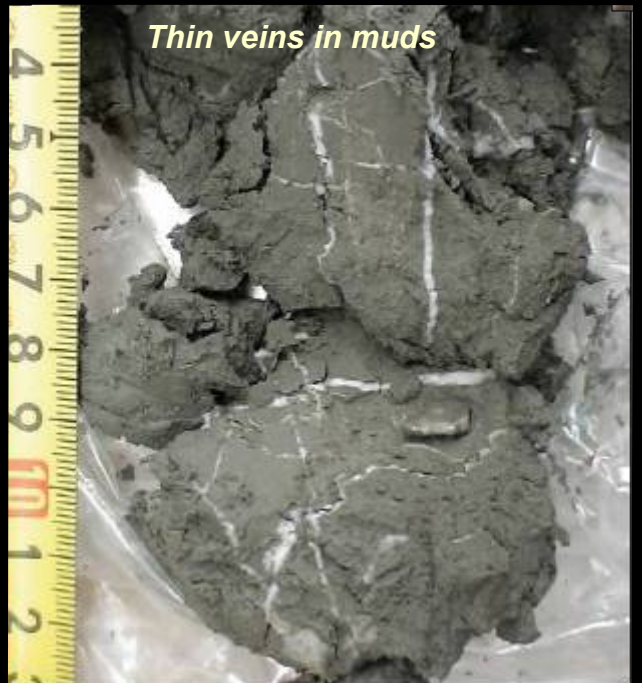
- Formation temperature
- Formation pressure
- Pore water salinity
- Gas chemistry
- Availability of gas and water
- Gas and water migration pathways
- Presence of reservoir rocks and seals

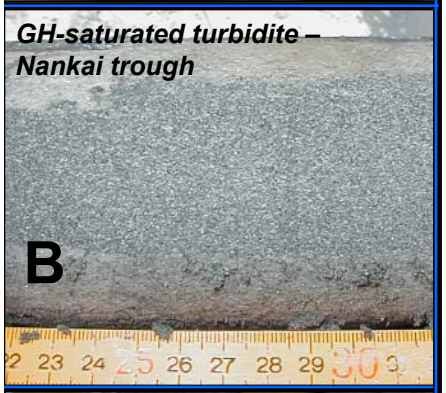


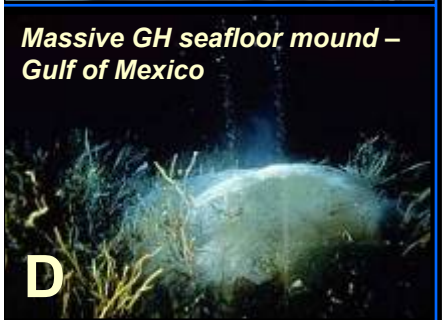




GAS HYDRATES IN NATURE

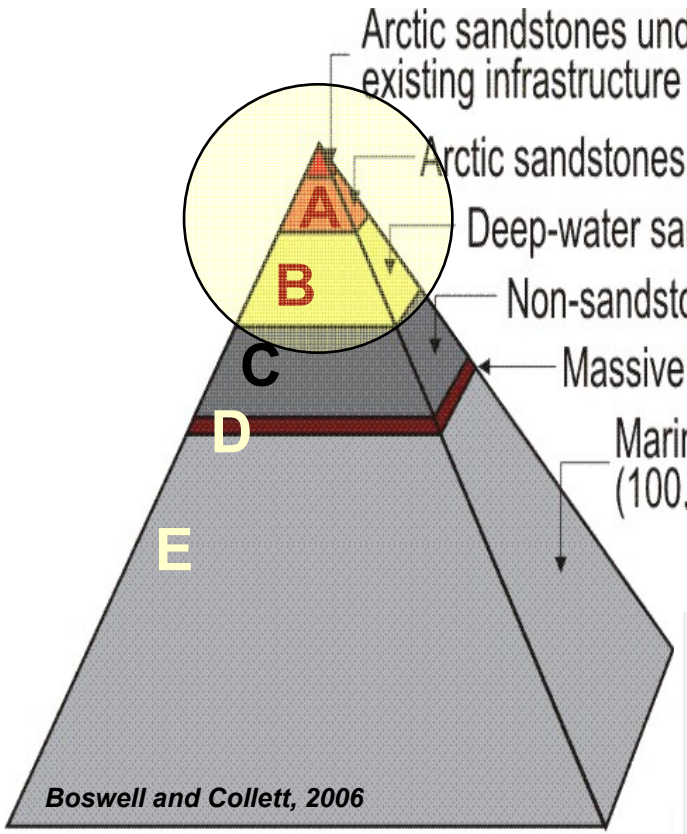






The Gas Hydrates Resource Pyramid

Distribution of huge in-place resource



Arctic sandstones under existing infrastructure (~10's of Tcf in place)

Arctic sandstones away from infrastructure (100s of Tcf in place)

Deep-water sandstones (~1000s of Tcf in place)

Non-sandstone marine reservoirs with permeability (unknown)

Massive surficial and shallow nodular hydrate (unknown)

Marine reservoirs with limited permeability (100,000s Tcf in place)

Data Sources

A: Collett, 1993; Collett, 1995

B: MMS, 2008

C: Unassessed (India, Korea expeditions)

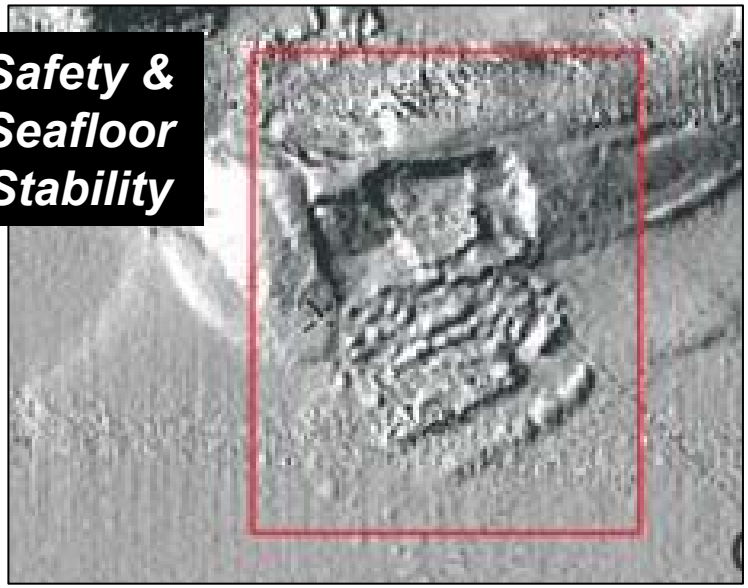
D: Unassessed

E: Collett, 1995

- **increasing in-place resource**
- **increasing uncertainty of resources**
- **decreasing reservoir quality**
- **increasing technical challenges**
- **decreasing % recoverable**

Current Gas Hydrate R&D Issues

Safety & Seafloor Stability



Energy Resource Potential

JOGMEC, NRCan, Aurora – Mallik 2008

Global Environment

NOAA – Gulf of Mexico

Mount Elbert Well – Alaskan North Slope: February, 2007

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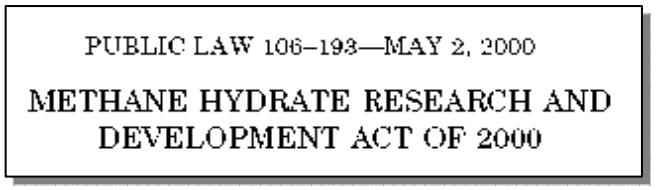
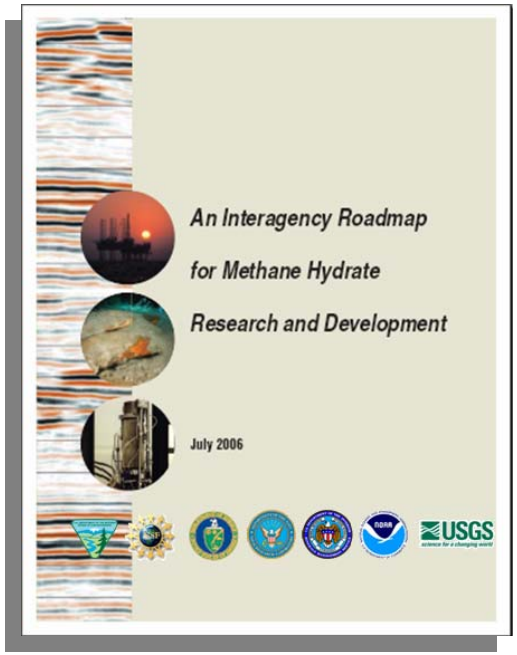
The DOE National Gas Hydrate R&D Program

Implementing the Methane Hydrates R&D Acts of 2000 & 2005

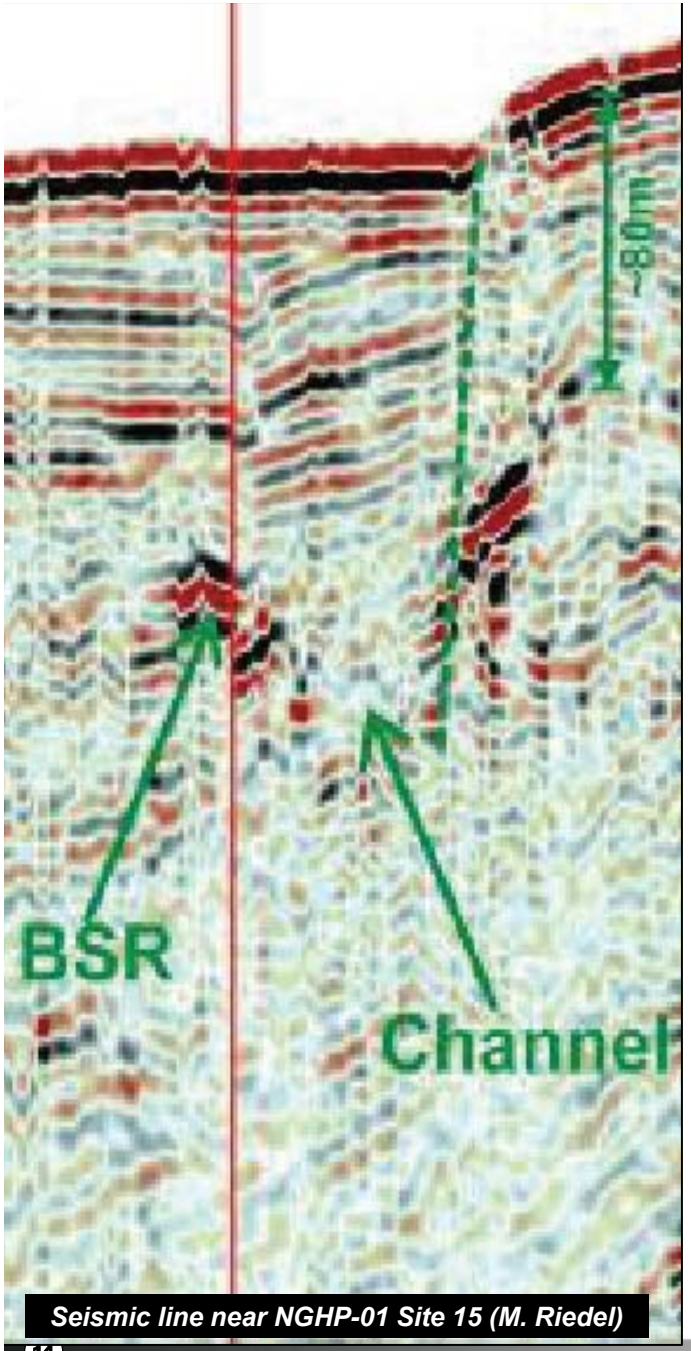
- **Seven collaborating federal agencies**
  - DOE-NETL led (National Labs)
  - DOI (BLM, USGS, MMS)
  - DOC (NOAA)
  - DOD (Naval Research Lab)
  - National Science Foundation
- **Program Focus & Goals**
  - realizing methane hydrates resource potential, and
  - understanding hydrate's role in the natural environment
  - supporting educational opportunities
  - international collaboration
- **Impacts**
  - Better informed ocean/climate policy
  - Potential new domestic gas resource


PUBLIC LAW 106–193—MAY 2, 2000

METHANE HYDRATE RESEARCH AND DEVELOPMENT ACT OF 2000



Additional information at www.netl.doe.gov/methanehydrates



Seismic line near NGHP-01 Site 15 (M. Riedel)

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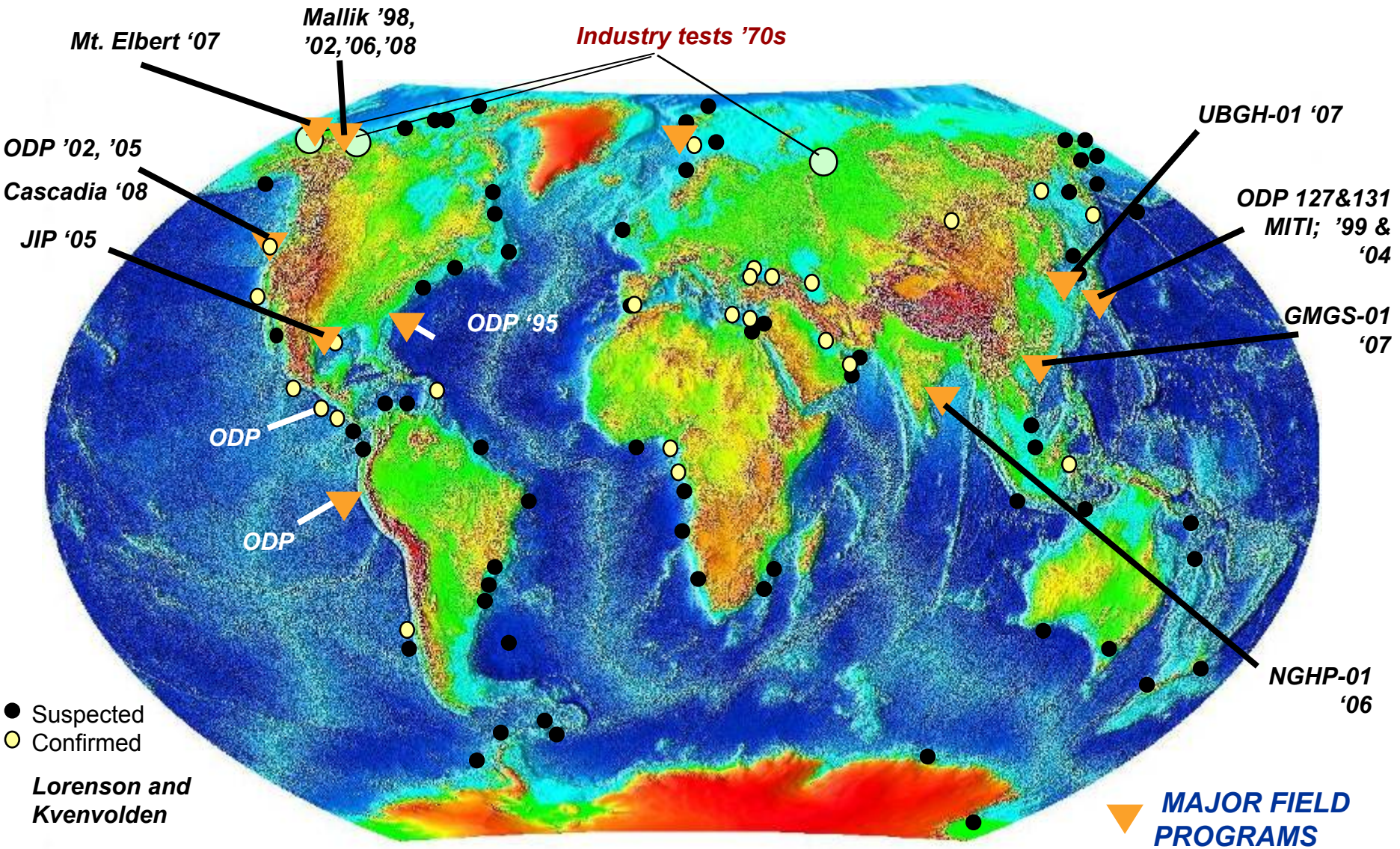
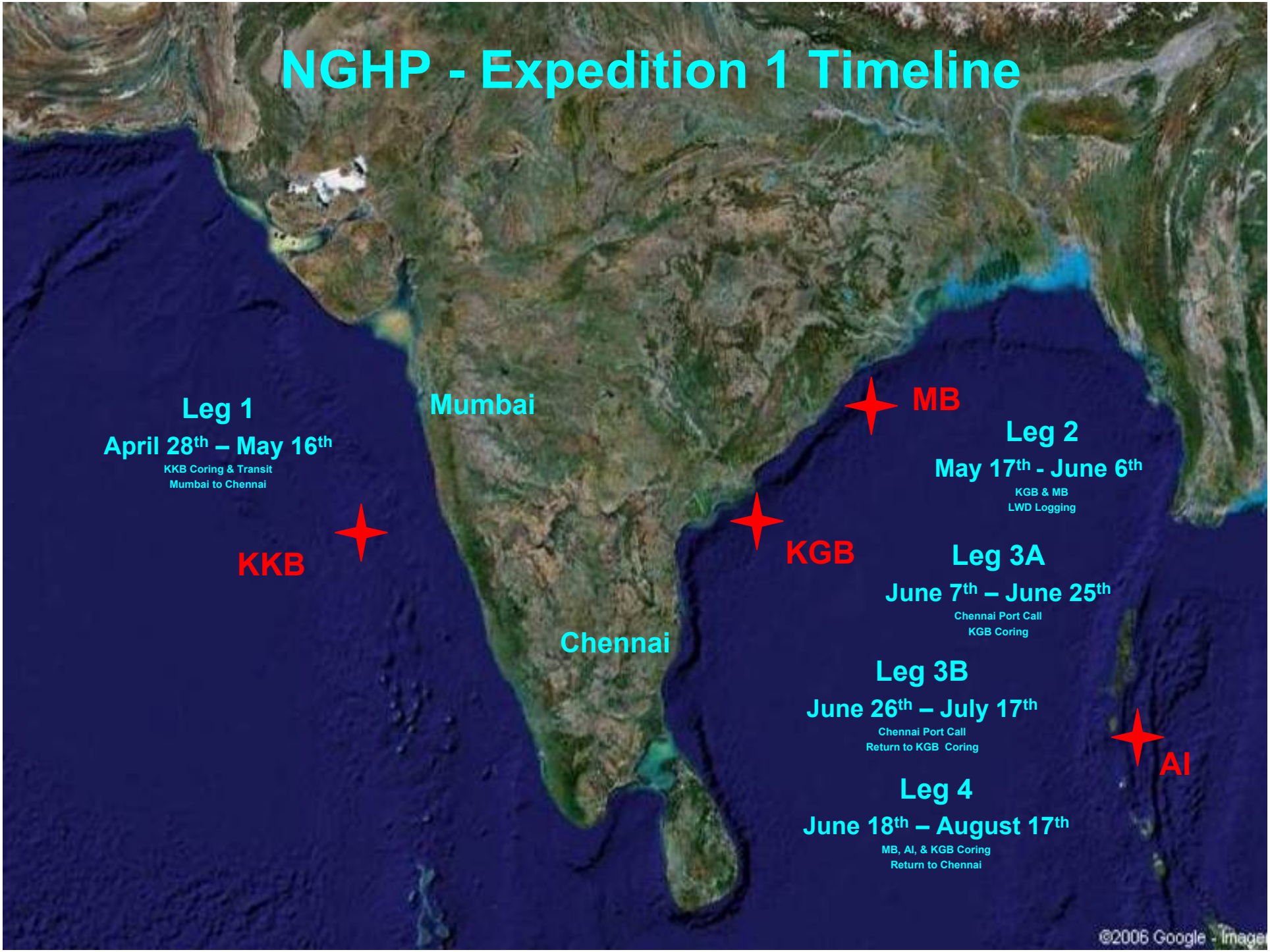
Global Gas Hydrate R&D



US DOE - International Collaboration


NGHP - Expedition 1 Timeline
Leg 1
April 28th – May 16th
KKB Coring & Transit
Mumbai to Chennai
Mumbai
KKB
MB
Leg 2
May 17th - June 6th
KGB & MB
LWD Logging
KGB
Leg 3A
June 7th – June 25th
Chennai Port Call
KGB Coring
Chennai
Leg 3B
June 26th – July 17th
Chennai Port Call
Return to KGB Coring
AI
Leg 4
June 18th – August 17th
MB, AI, & KGB Coring
Return to Chennai
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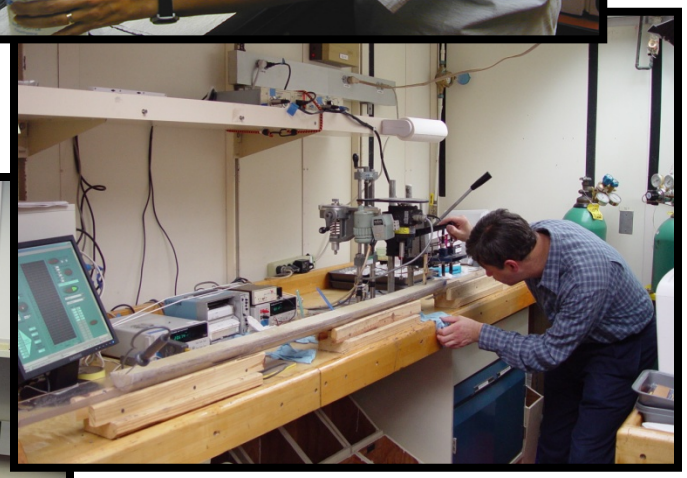
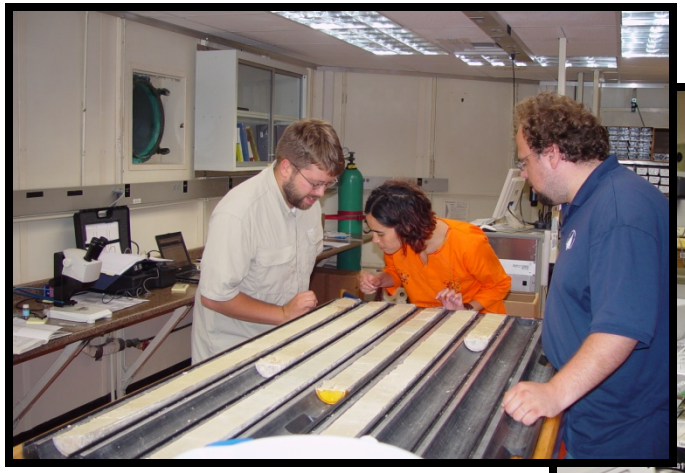
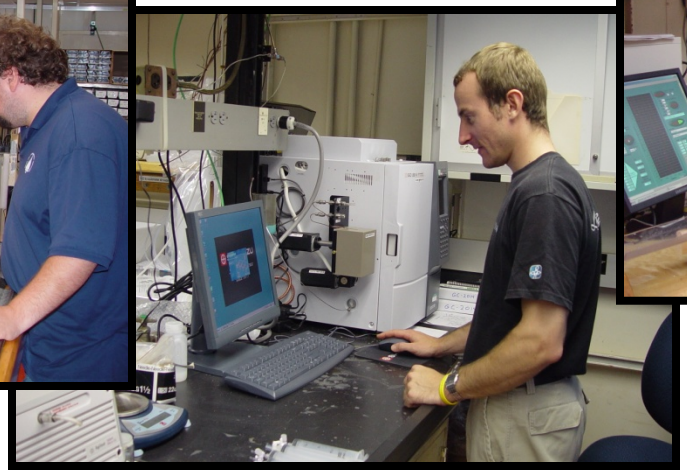
NGHP-01 Shipboard Laboratories

- Physical Properties Measurements
- Sedimentologic Descriptions
- Organic Geochemisty
- Inorganic Geochemistry
- Microbiology Studies



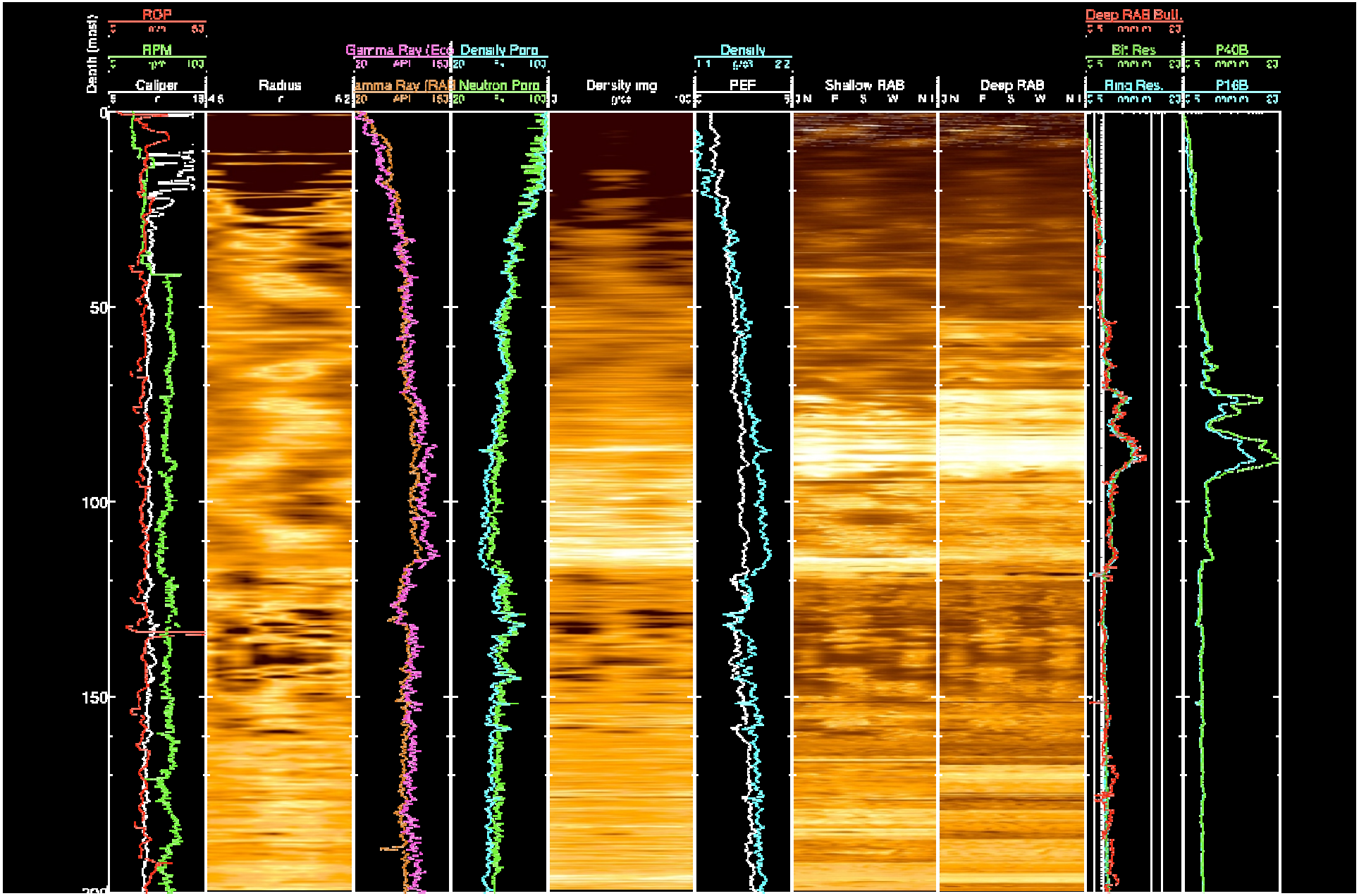




NGHP Exp-1 Tool Deployments

- APC: Advanced Piston Corer
- XCB: Extended (Rotary) Core Barrel
- APCT/APC3: Temperature Tool (APC coring shoe)
- APC-Methane Tool: TPC Sensors in APC Piston
- DVTP: Davis-Villinger Temperature Probe
- PCS: ODP Pressure Core Sampler
- HRC: HYACE Rotary Corer
- FPC: FUGRO Pressure Corer
- LWD/MWD: Logging/Measurement While Drilling
- CWL: Conventional Wireline Logging
- VSP: Vertical Seismic Profiling

LWD Data


Depth (mast)
ROP
RPM
Caliper
Radius
Gamma Ray (Ecc
Gamma Ray (RAB
Density Poro
Neutron Poro
Density img
Density
PEF
Shallow RAB
Deep RAB
Deep RAB Bull.
Bit Res
Ring Res.
P40B
P16B
0
50
100
150

Physical Properties

Whole Rounds

Thermal Conductivity

MSCL

- **Gamma density**
- **Vp**
- **Electrical Resistivity**
- **Magnetic Susceptibility**

Split Cores

Contact electrical resistivity

Vp (double-spade technique)

Shear strengths

- **Mini vane shear**
- **Torvane**
- **Pocket penetrometer**

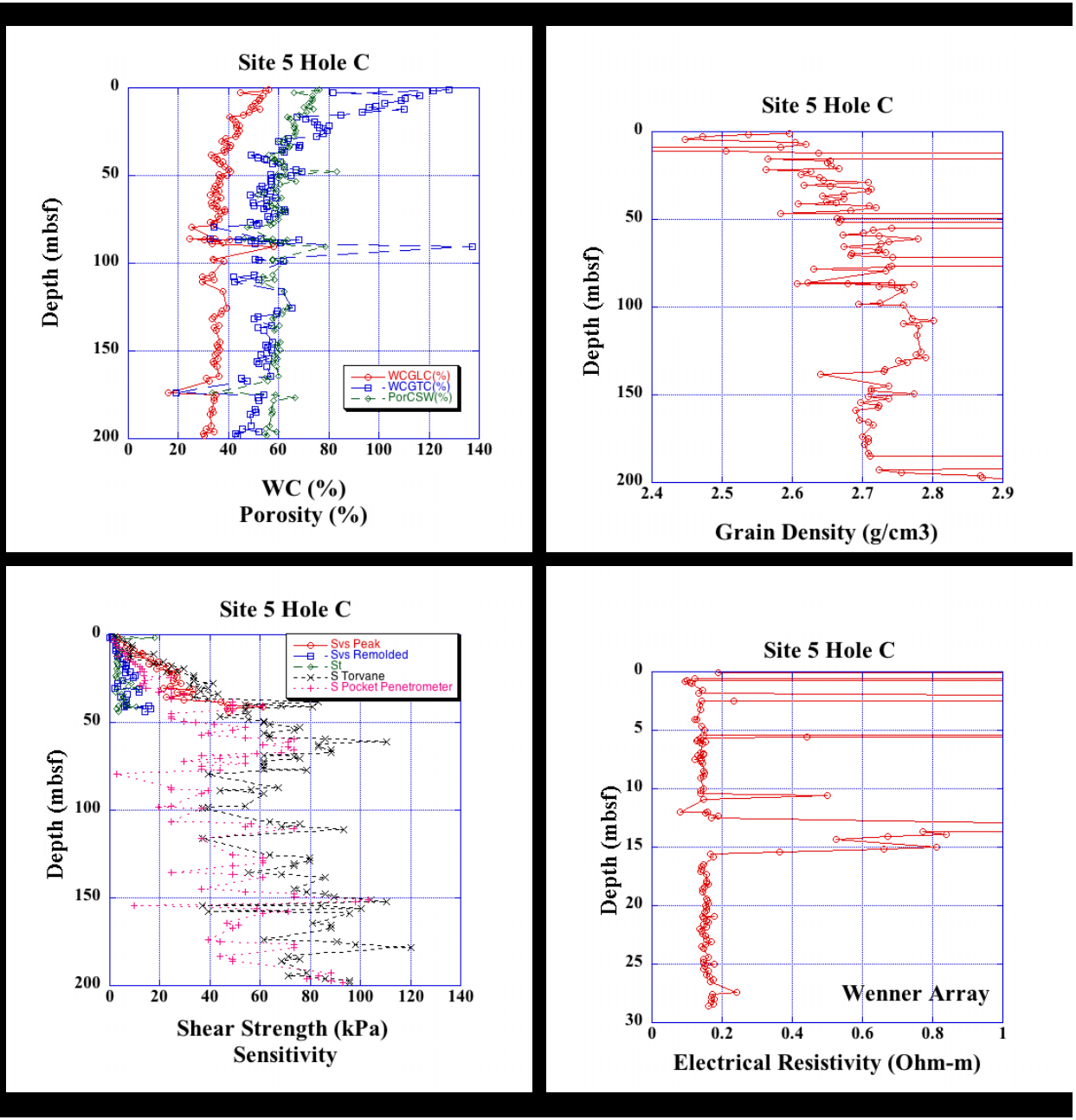
Index

Water contents

- **Grain density**
- **Porosity**
- **Densities**
- **Vertical stress**

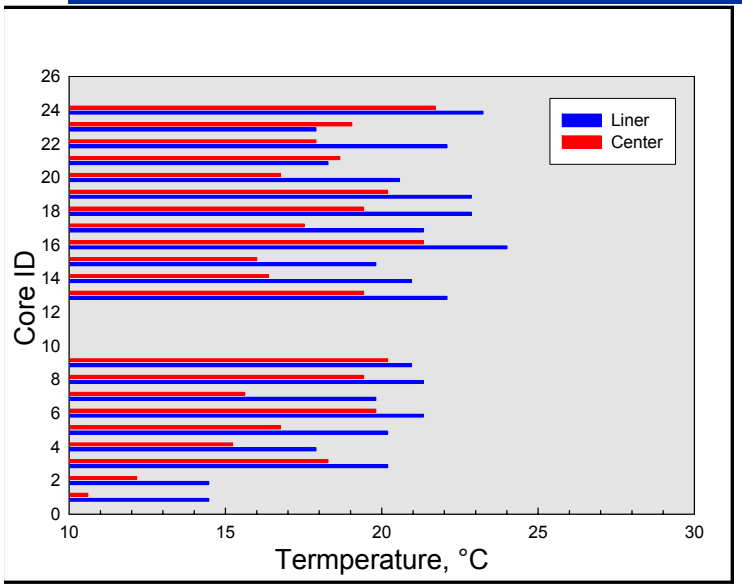
Grain size

Consol/triaxial/GHASTLI



IR Imaging and Temperature Results

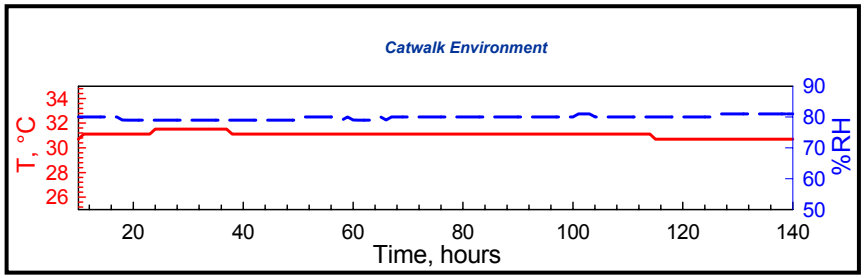
Core End Temperatures 5C

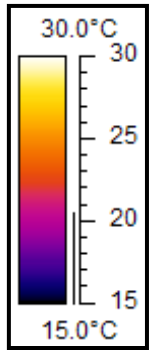


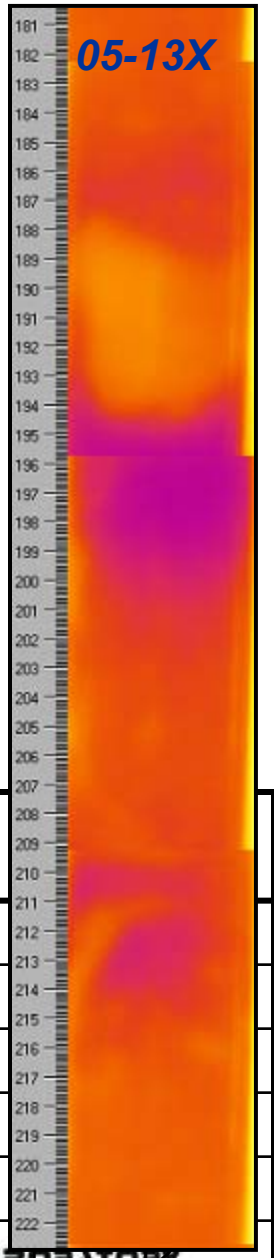
IR Hand Held Camera

IR Track Imaging

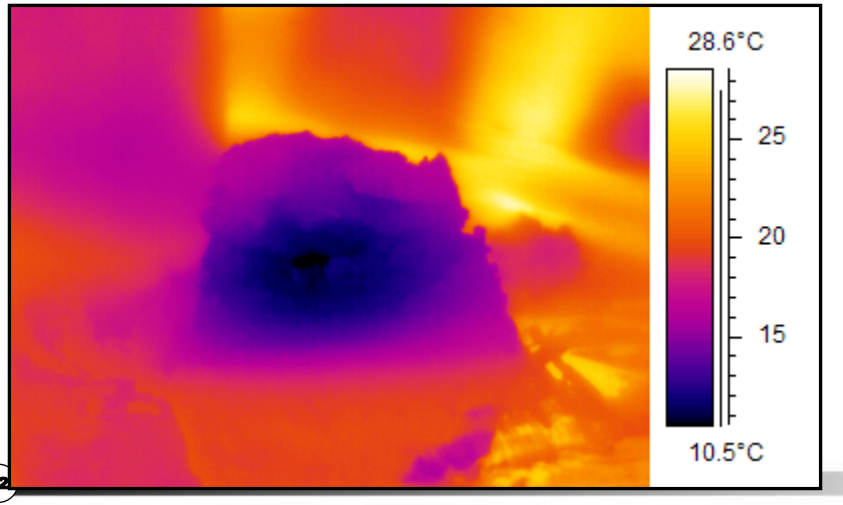
- Number of Scans
  - 5C - 24
  - 5D - 4
- IR Anomalies
  - 1 in Core 13
  - 1 in Core 14



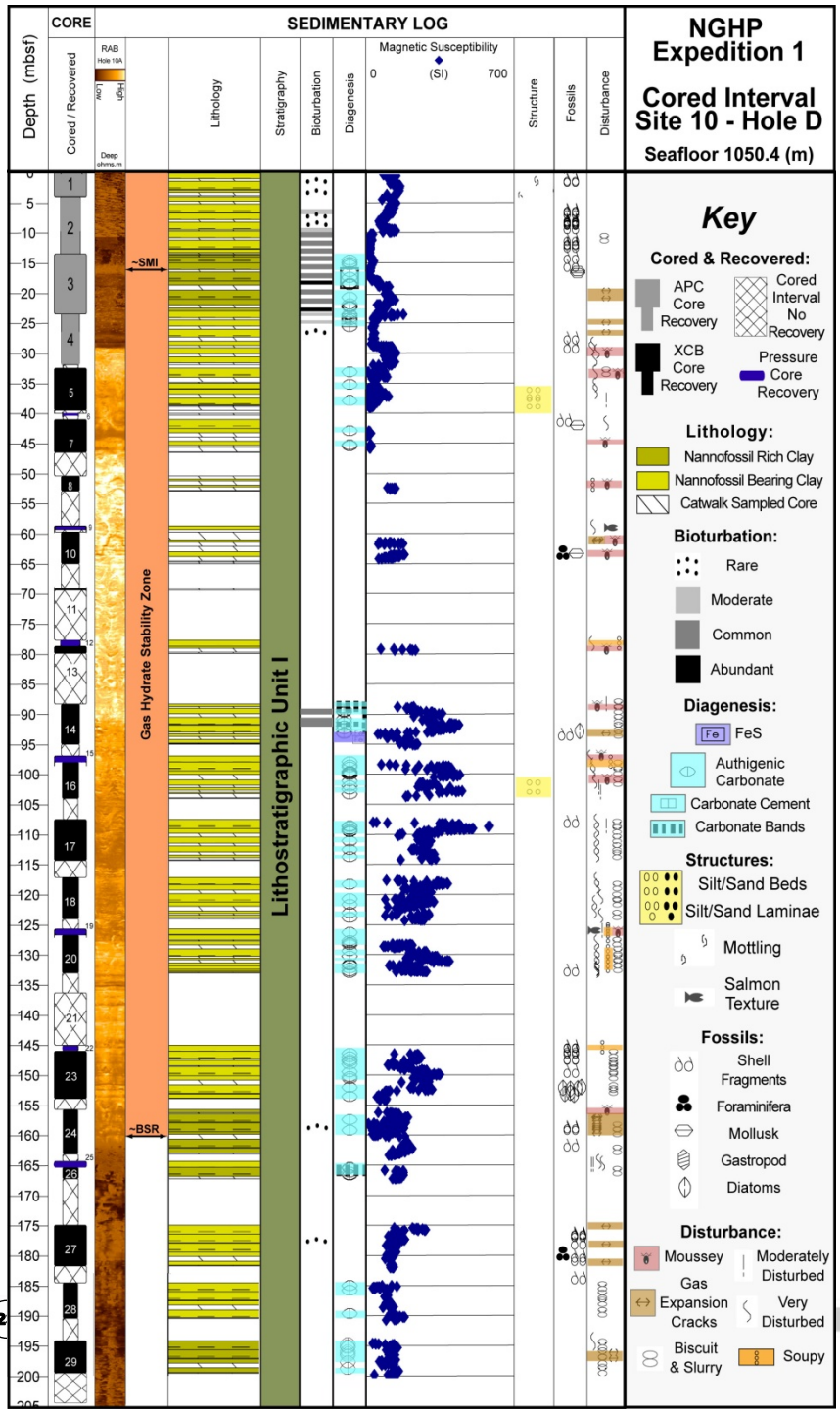




IR Core Analysis 5C



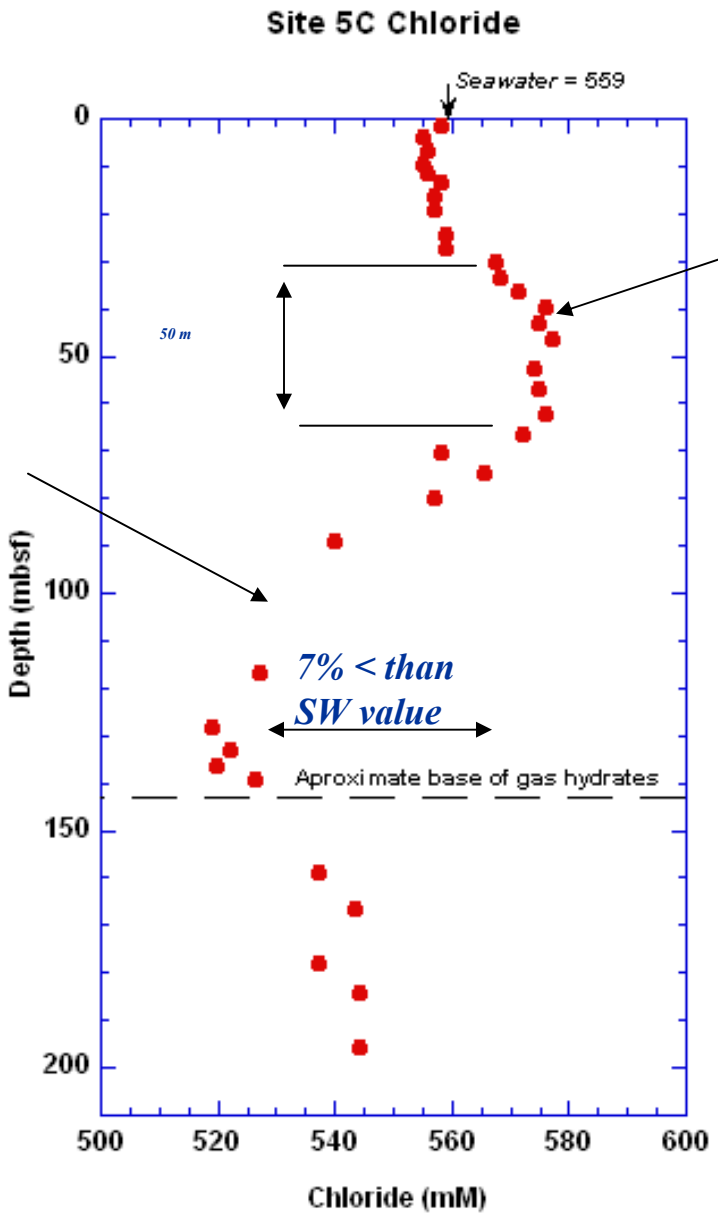
Core ID	
5C-5	
5C-7	
5C-8	
5C-9	
5C-13	
5C-14	14



Lithostratigraphic Contributions

- **Detailed descriptions of archival cores**
- **Identification of sediment compositions**
  - Primary & secondary minerals
  - Nanno and Micro fossils
  - Organic material
- **Secondary precipitates**
  - Authigenic carbonates
  - Iron sulfides, etc
- **Identification of Sedimentary Structures**
  - Silt or Sand beds
  - Silt or Sand laminae
  - Fractures, etc.
- **Core disturbance features**
  - Moussey
  - Expansion cracks
- **Interpretation of Depositional History**

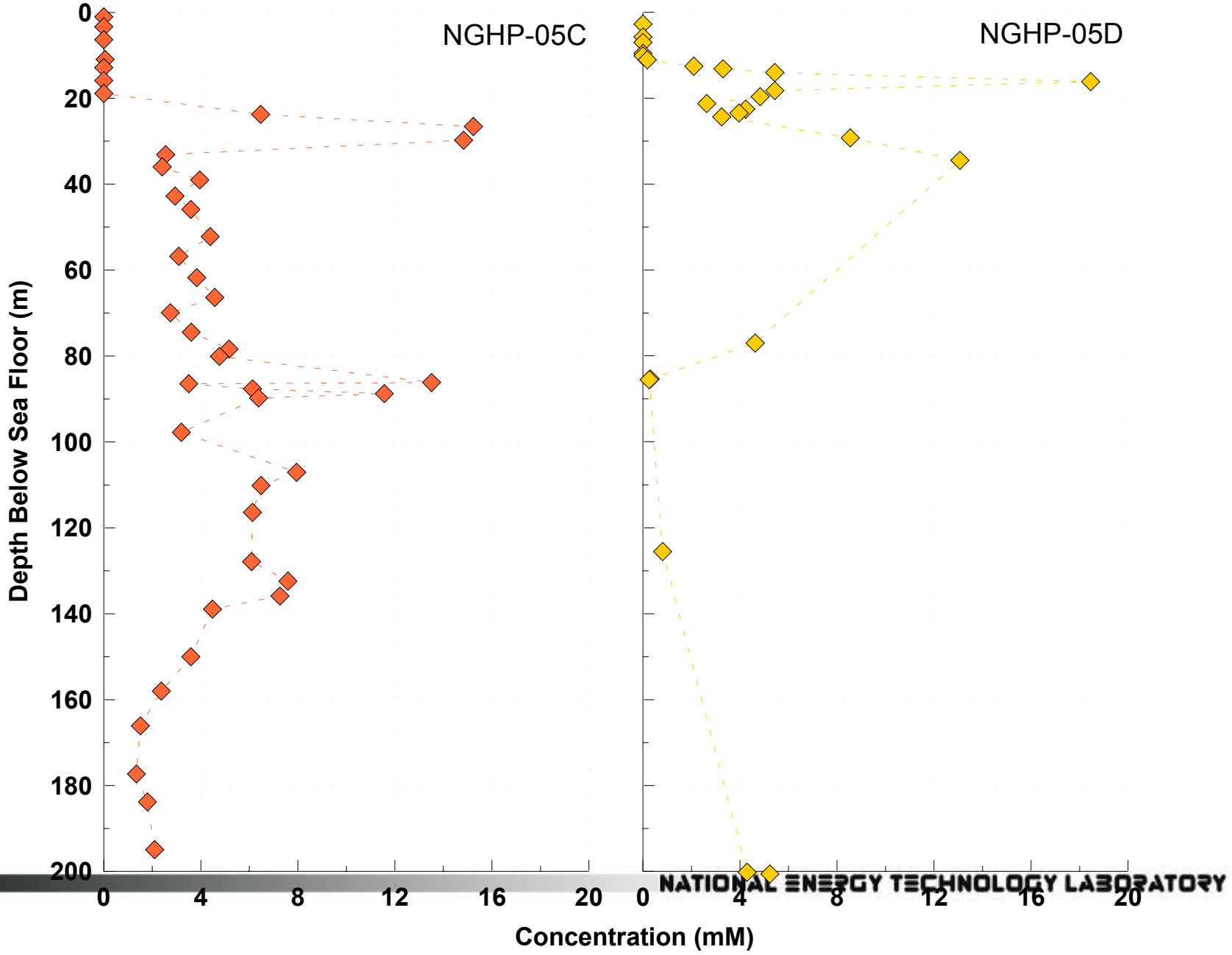
Inorganic Geochemistry – Chloride Concentrations



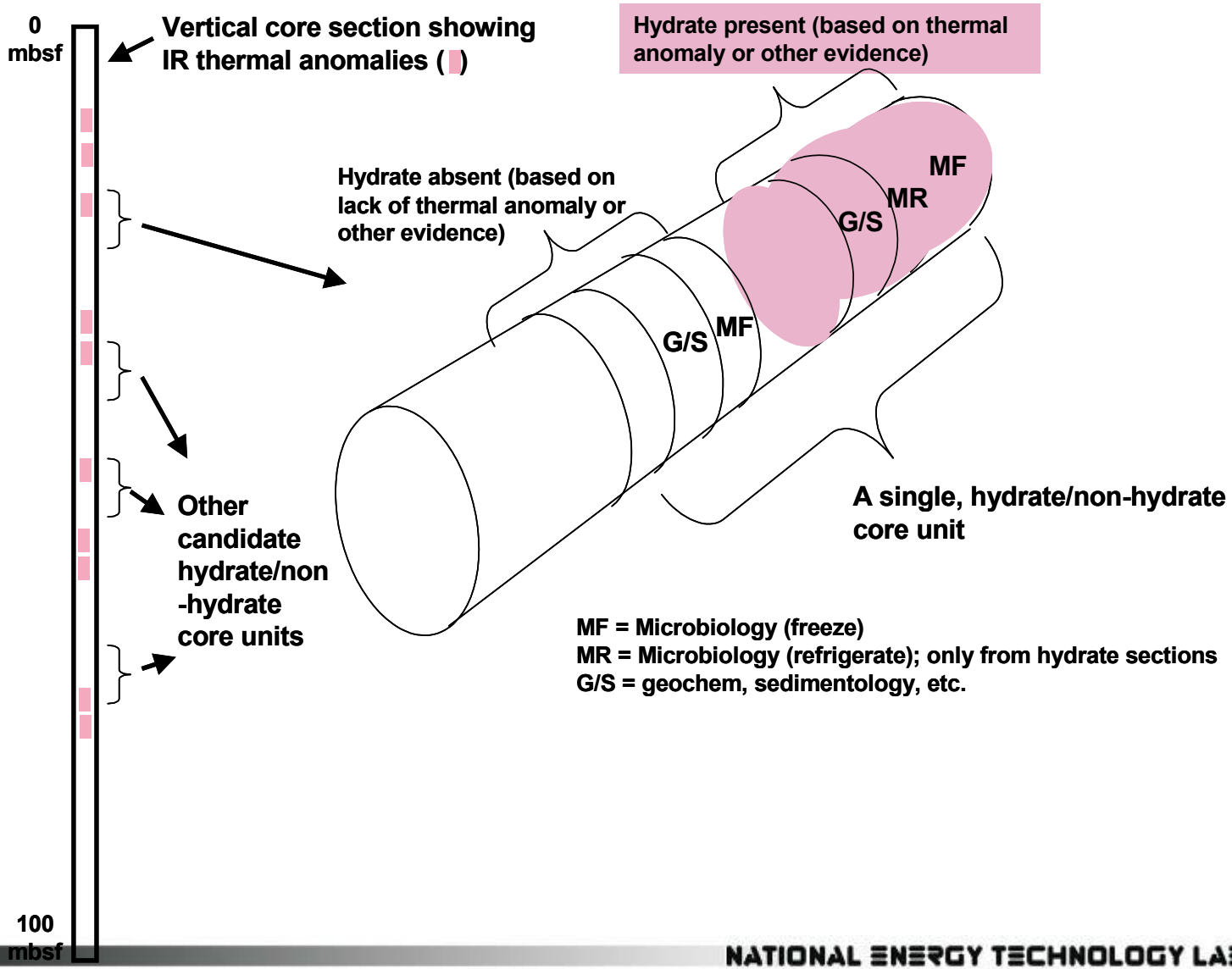
Interglacial water ?
Cl ~ 579 mM

Gas hydrate dissociation during core recovery

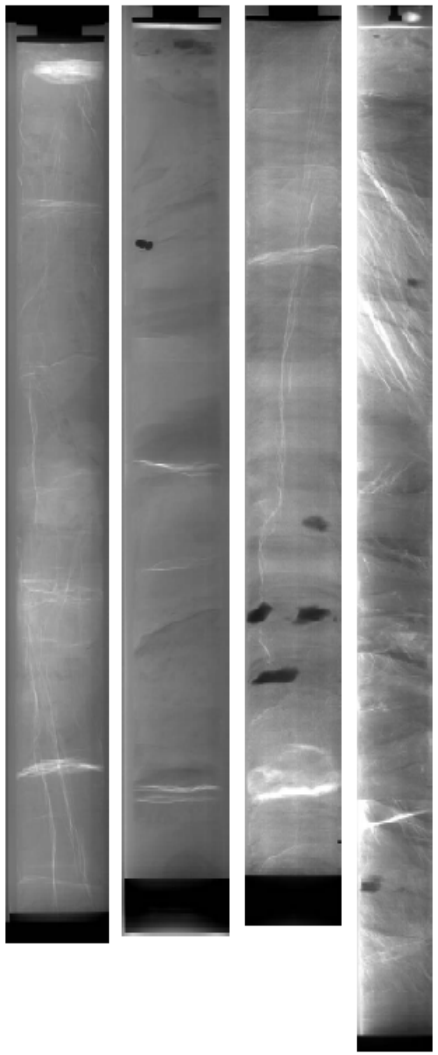
Organic Geochemistry – Headspace Methane



Microbiological Sampling

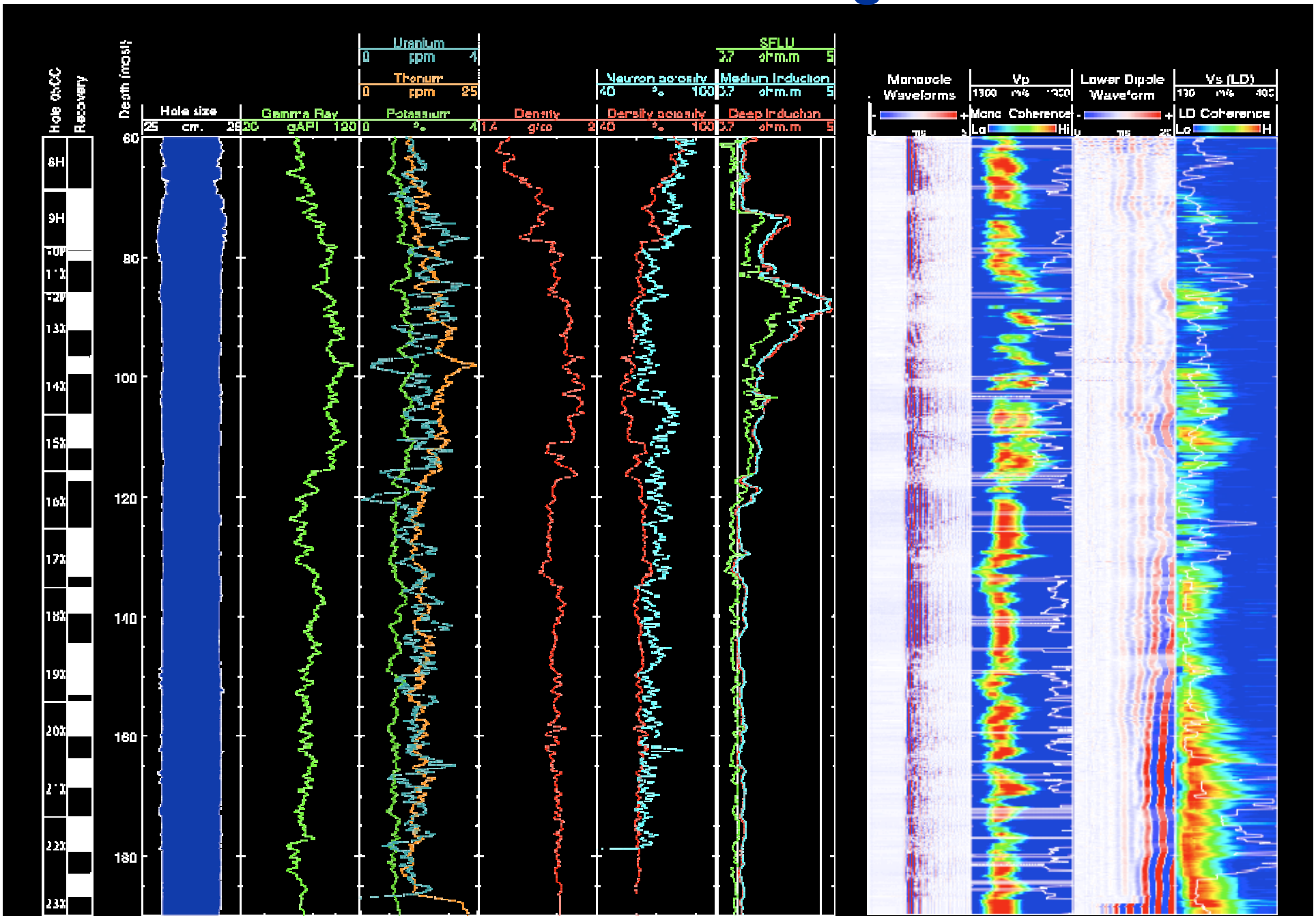


Measurements at In-Situ Pressure



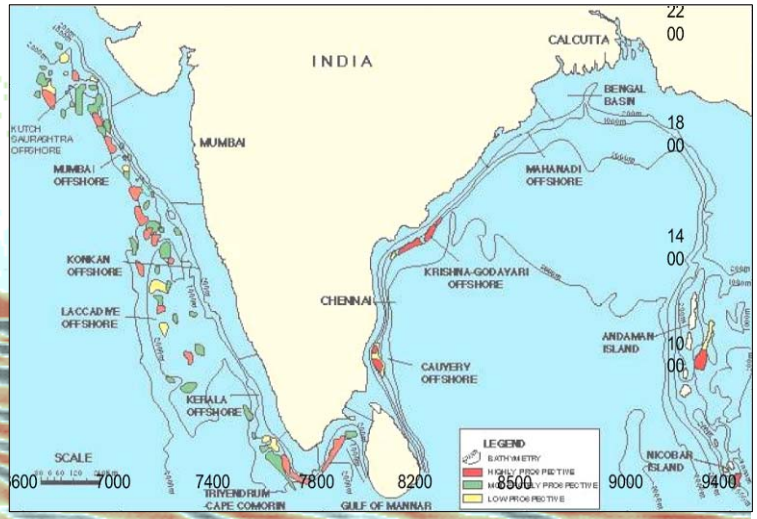
- X-rays
- Gamma density
- Acoustic velocity

NGHP Wireline logs



Hydrates In the Indian Ocean

Pre-expedition Evidence



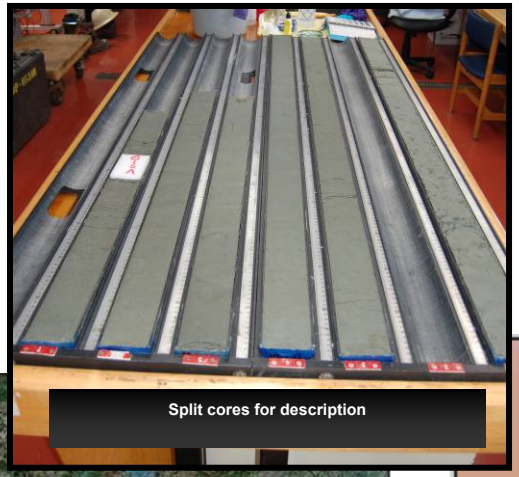
Stability zone: 15 Tcf estimated

BSR

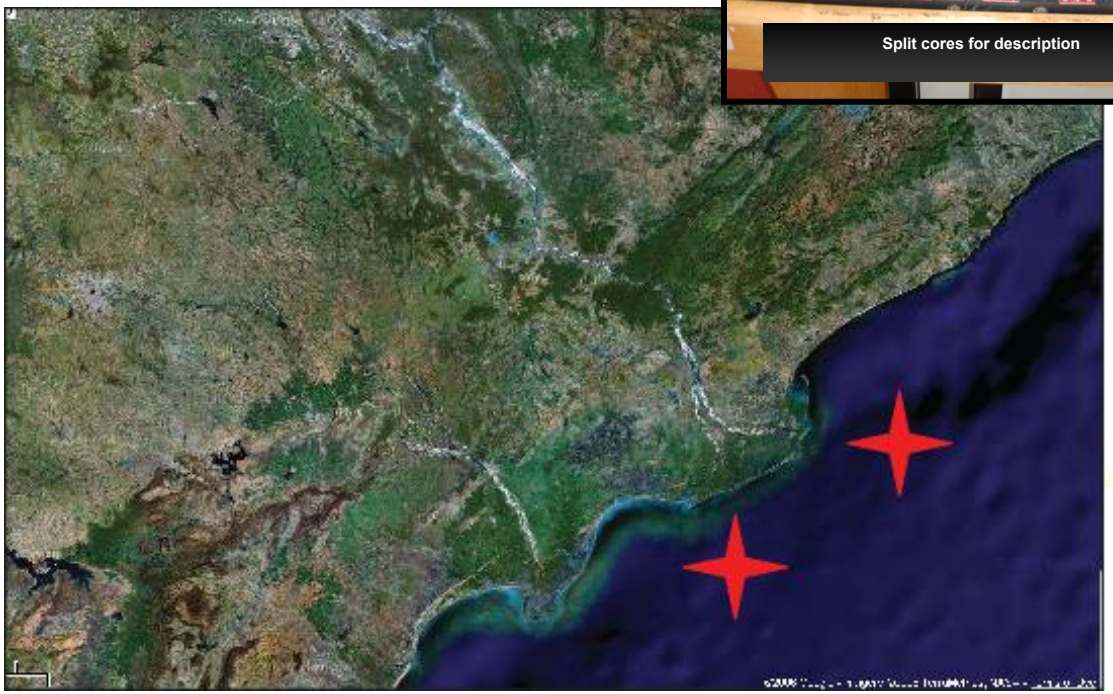
Free gas accumulation: 25 Tcf estimated

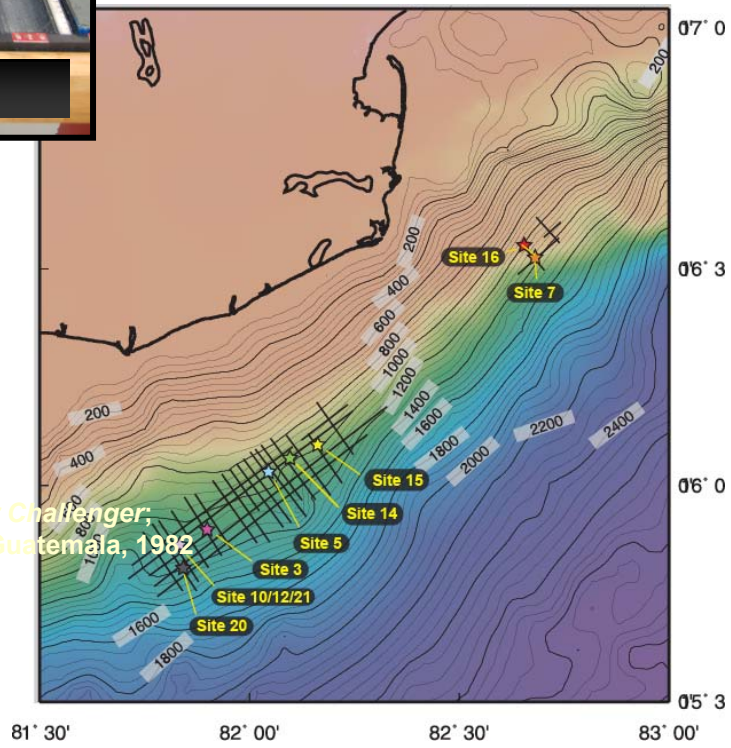
Natural Gas Hydrates in the KG Basin

- **Lithologic Components:**
  - Nannofossil, foram, & smectite bearing to rich clays
  - Rare, thinly bedded silt/sand beds & laminae (mm to cm)
  - High terrigenous organic carbon content



- **Secondary Precipitates**:
  - Authigenic carbonates
  - Iron sulfides
  - Gas hydrates, primarily disseminated, nodules, & fracture fill

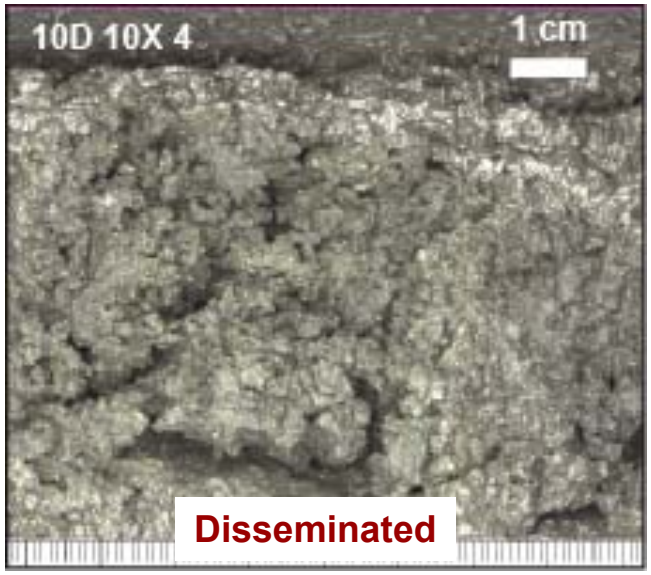




ar Challenger;
Guatemala, 1982

Primary Gas Hydrate Accumulations
Within Clay Lithologies

IR scan and corresponding split core images of nannofossil bearing to rich clay in the GHSZ. The IR anomalies document the presence of hydrate throughout this impermeable lithofacies.



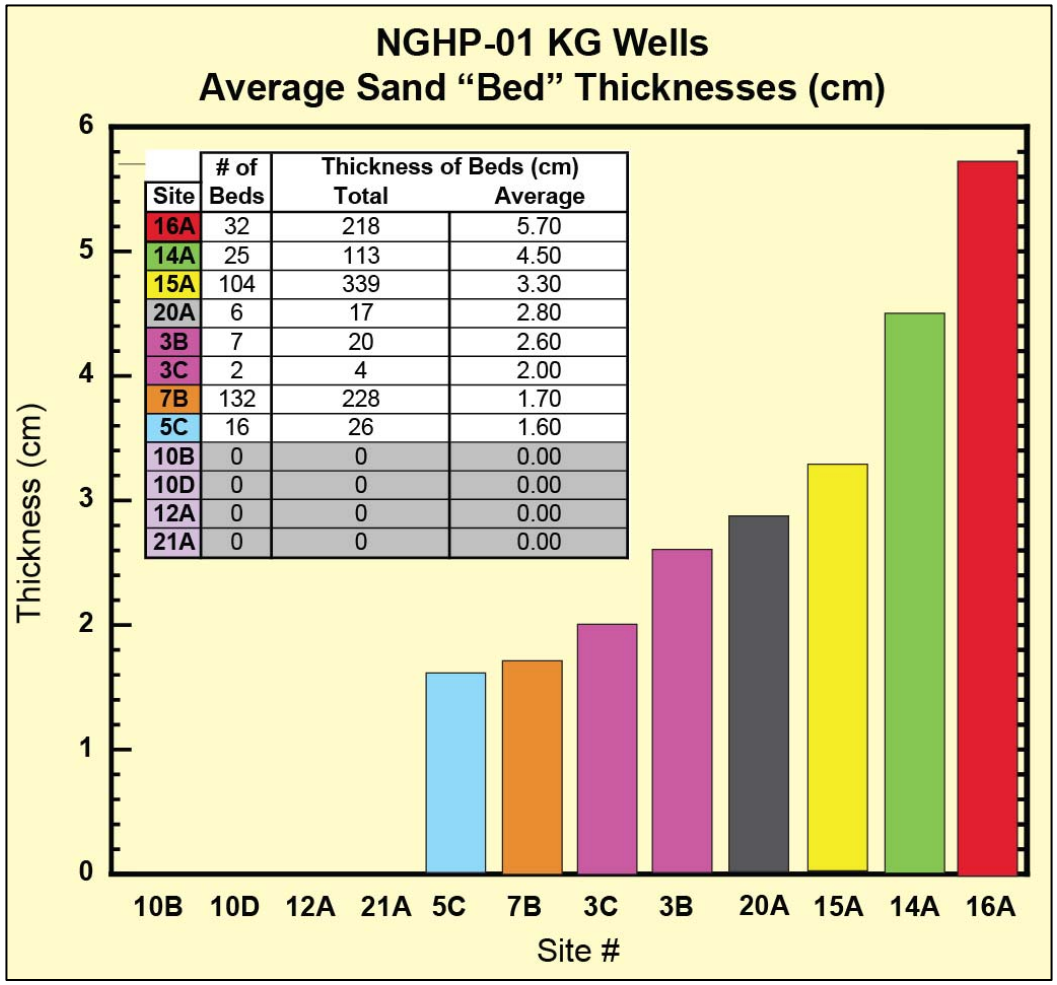
Disseminated

Massive

Fracture fill

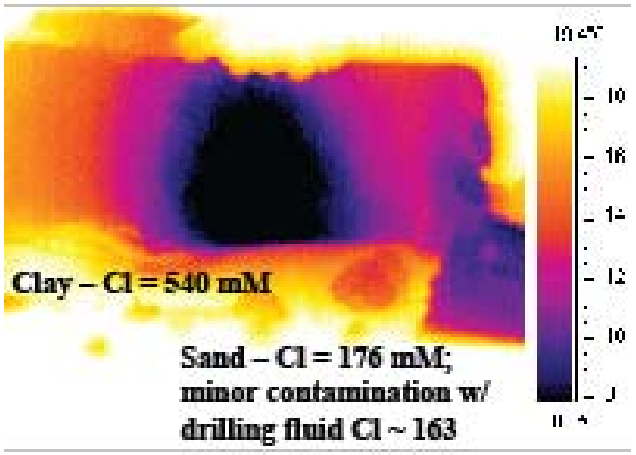
Secondary Accumulations

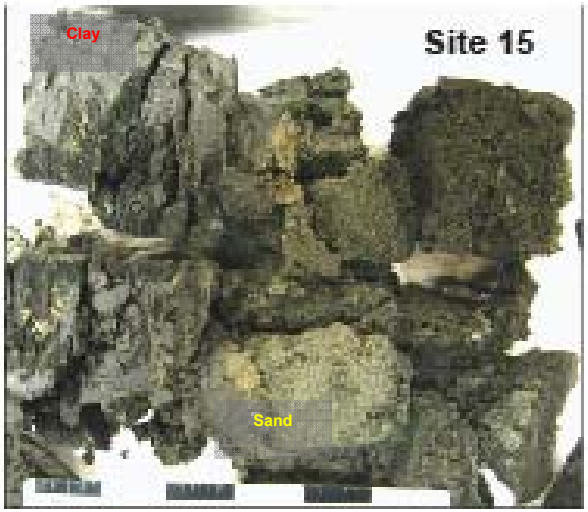
Porous & Permeable Lithologies



Site	# of Beds	Thickness of Beds (cm) Total	Average
16A	32	218	5.70
14A	25	113	4.50
15A	104	339	3.30
20A	6	17	2.80
3B	7	20	2.60
3C	2	4	2.00
7B	132	228	1.70
5C	16	26	1.60
10B	0	0	0.00
10D	0	0	0.00
12A	0	0	0.00
21A	0	0	0.00

Rare coarser grained, permeable facies are present in the form of thin, mm to cm, sand & silt laminae and beds





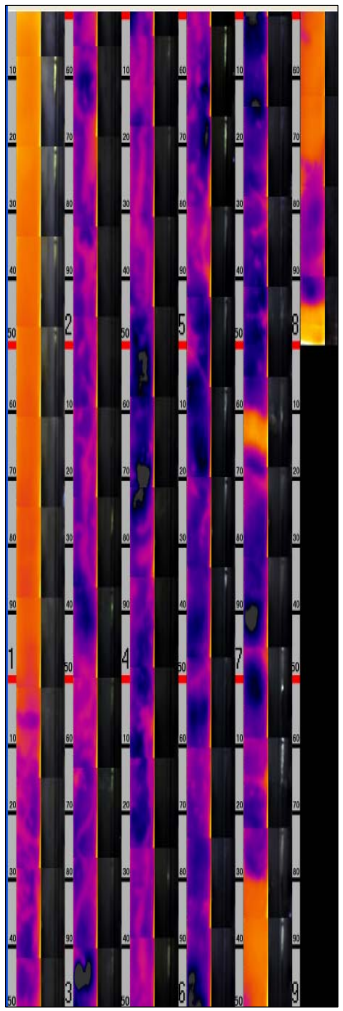
Core photo & corresponding IR image of GH bearing sediments

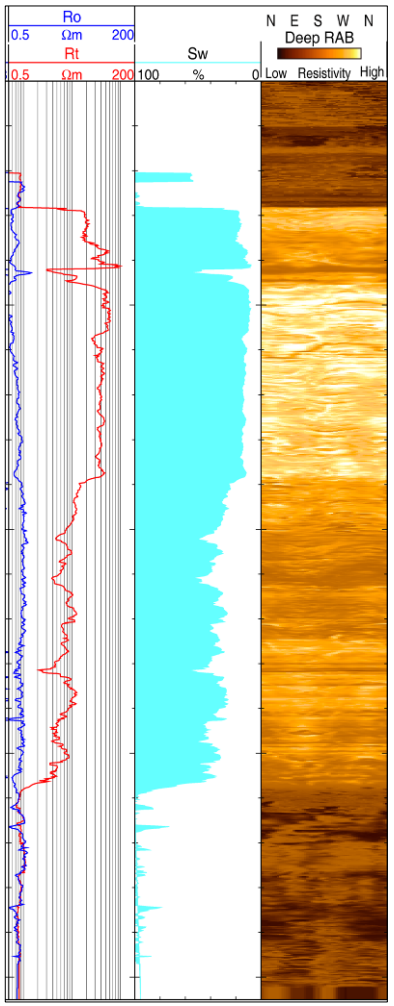
Krishna-Godavari Basin

Site 10/21 - Richest Hydrate Locality Yet Discovered?

- 130-meters of hydrate-bearing section
- Log-calculated GH saturations of 60-80%
- Fracture-controlled distribution w/in a shale matrix
- Produceable?
- Limited areal extent

Pressure core images documenting hydrate bearing i) anastomosing fractures & ii) sub-horizontal nodules & layers

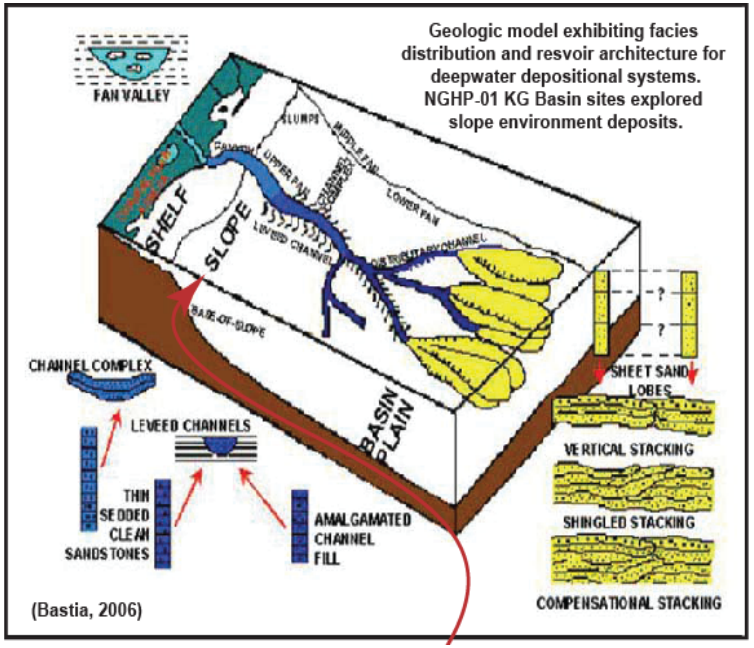




KG System Summary

- **Slope dominated, deep marine depositional system**
- **Low permeability marine hydrate system with structural overprint**
  - Disseminated gas hydrate in fine grained marine clay lithofacies dominant form
  - Laterally discontinuous structural features, faults & fractures, control massive gas hydrate occurrences in veins, fractures & nodules
  - Pore-filling hydrate cemented sand/silt laminae & thin beds
- **Thicker beds of coarser grained, permeable facies are likely down-dip in basin plain turbidite/debris flow deposits**

Dr. Kumar holds (temporarily) a burning piece of nodular hydrate from Site 10

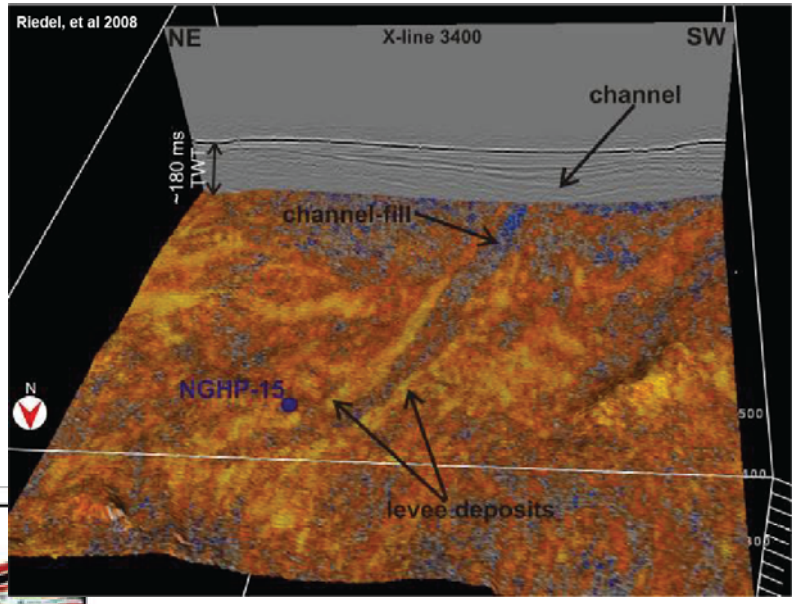


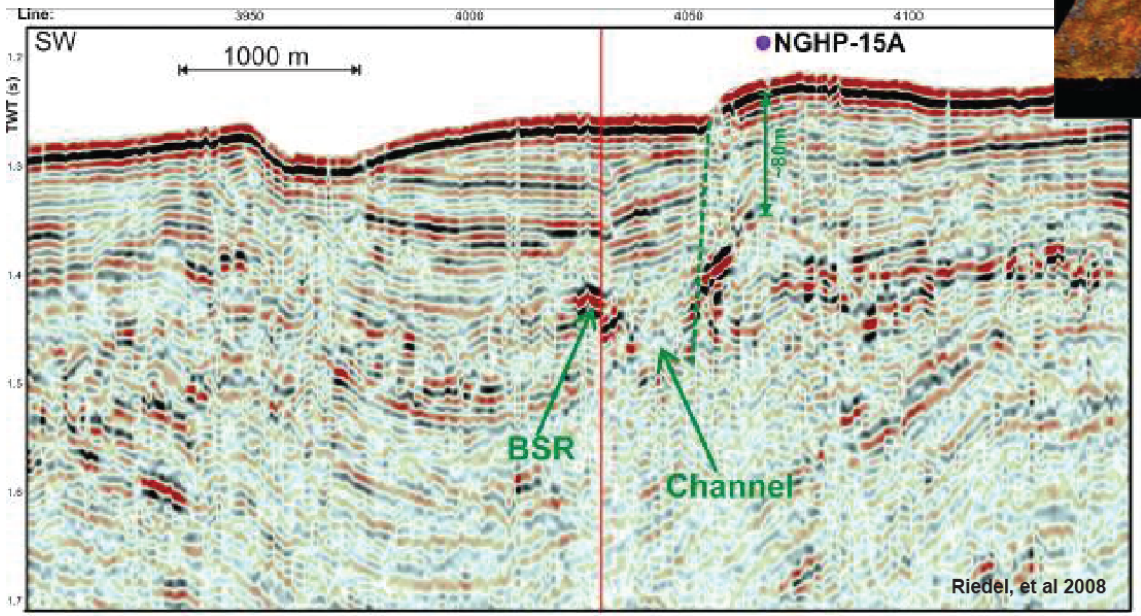
- Sea-level controlled slope deposition
- Mix of terrigenous and pelagic materials with increased coarse fraction delivery during lowstands

Future Exploration

More Porous and Permeable Units

- SW NE seismic line imaging a channel near Site 15
- The channel edges/levees appear to be coincident with the base of GHOZ
- These are potentially hydrate rich levee deposits given the reflection amplitudes of the events
- However the composition of the sediments is uncertain



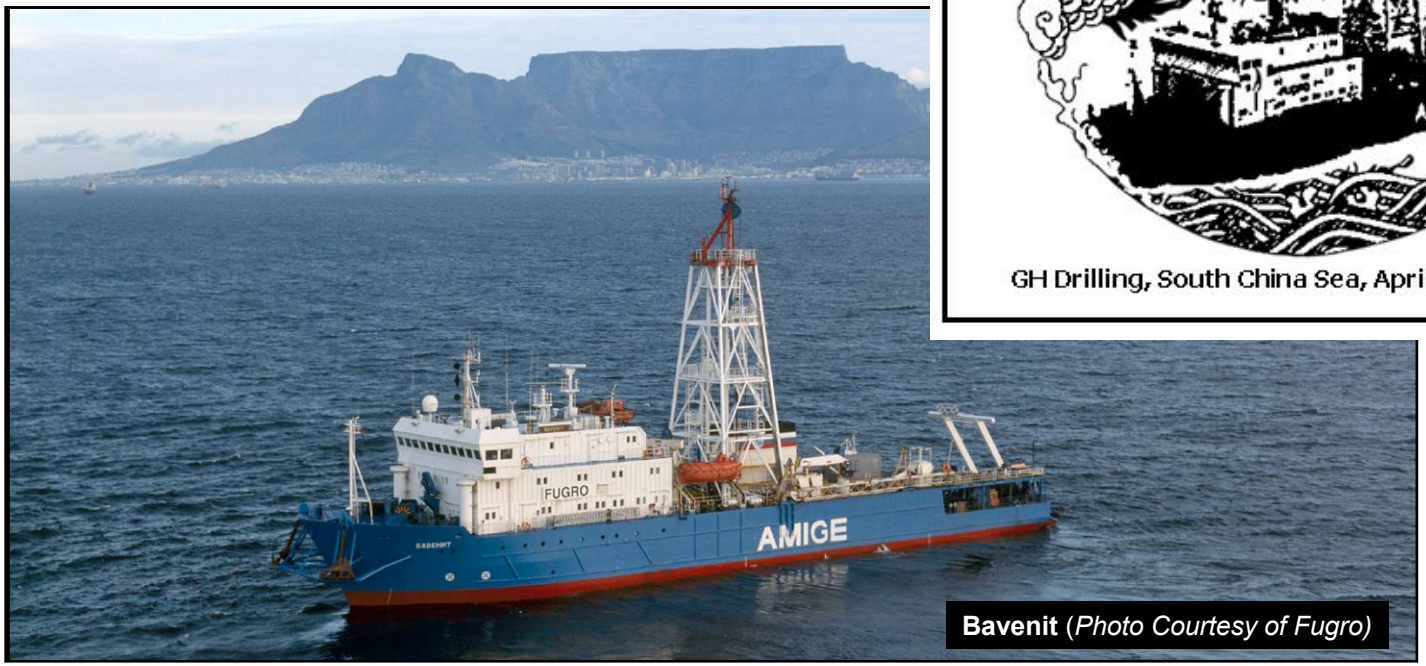


- Seismic attributes time slice
- Channel-levee system imaged
- High sweetness values, shown in yellow/orange, appear to be associated with levee-deposits
- The channel fill have lower sweetness values possibly indicating shalier content than the levees

GMGS-1 Gas Hydrate Expedition

April 21st – June 12th, 2007

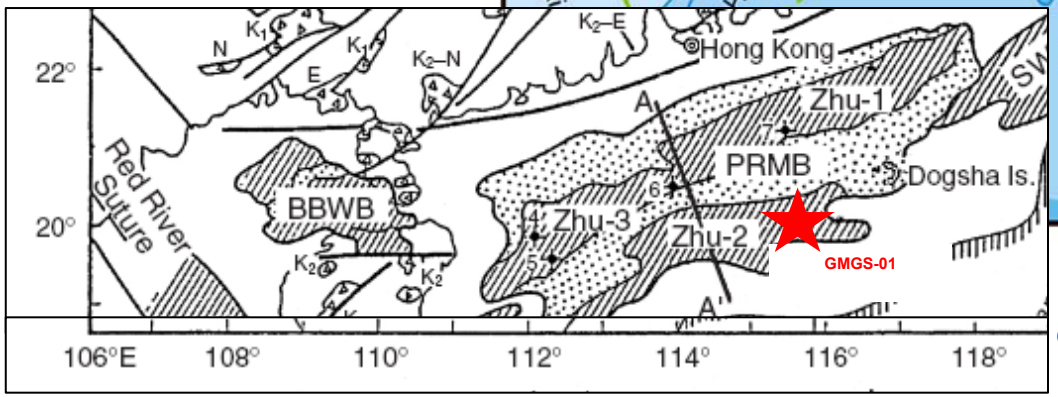
- **Principal Participants**
  - **Guangzhou Marine Geological Survey (GMGS)**
  - **China Geological Survey (CGS)**
  - **The Ministry of Land and Resources of P. R. China**
  - **Fugro**
  - **Geotek**



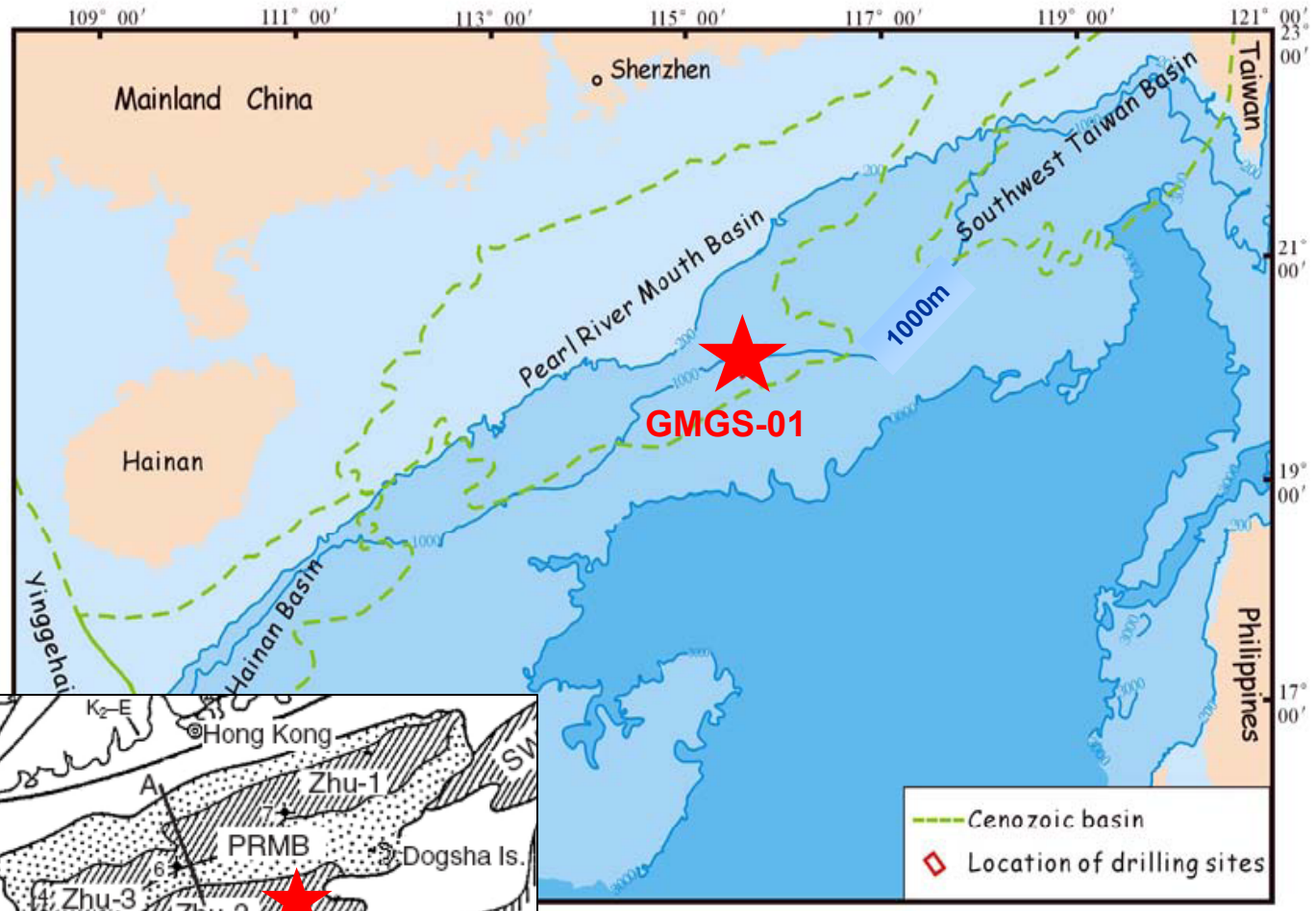
Bavenit (*Photo Courtesy of Fugro*)

Location & Geologic Setting

- Explored 8 sites in the South China Sea
- Water depths up to 1500m
- Drilled up to 300mbsf
- Tested precruise 3D seismic and shallow geochemistry based hydrate prospects

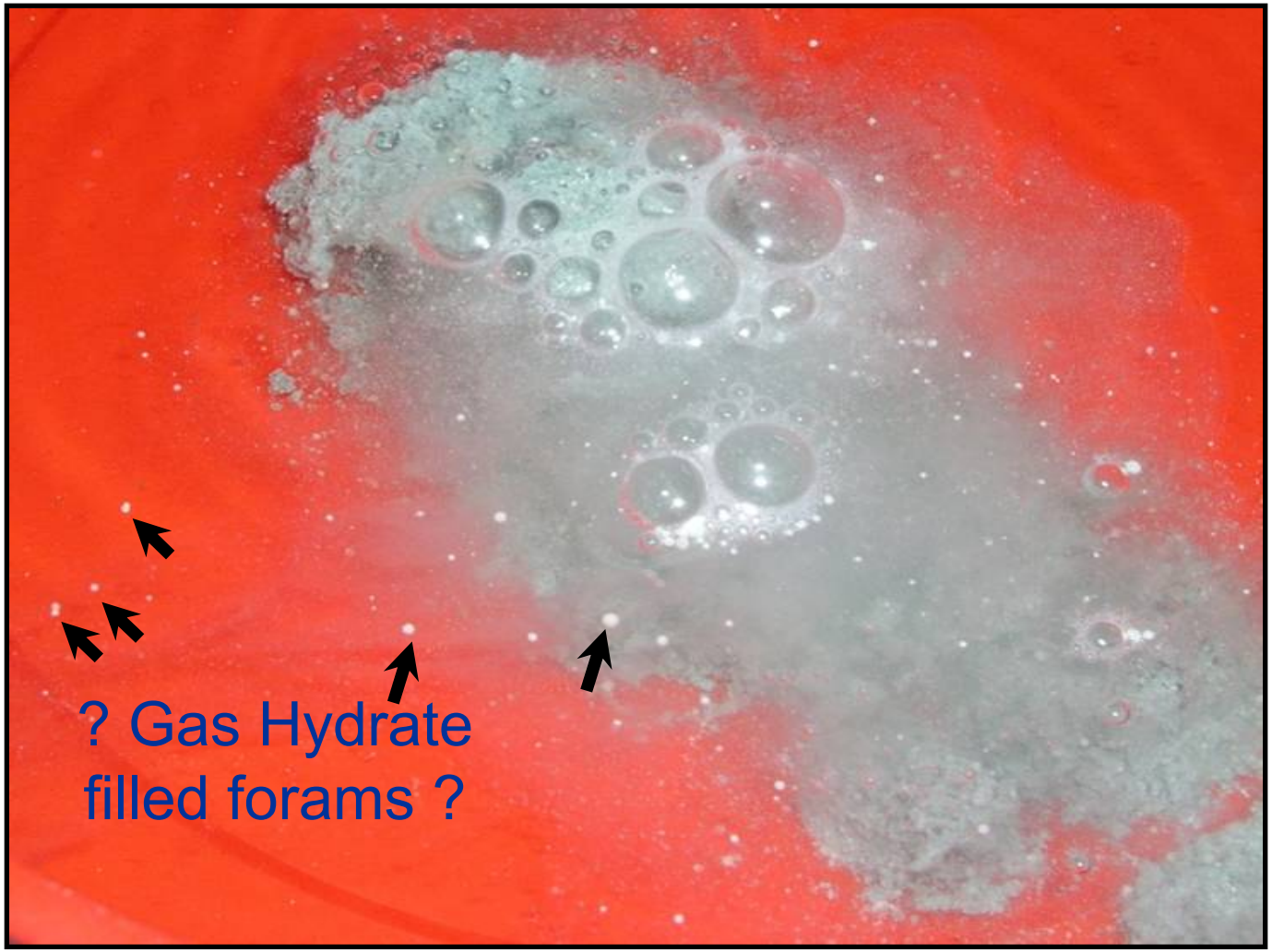


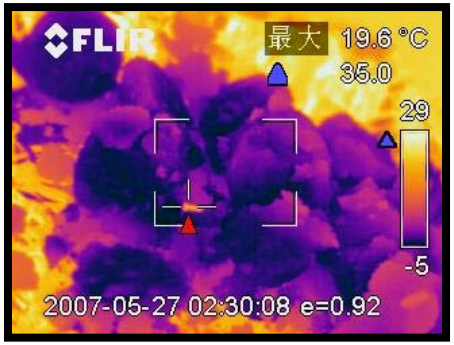
(modified from ODP Initial Report Leg 184)



GMGS-01 was located in the Zhu 2 sub-basin of the Pearl River Mouth Basin (PRMB).

GMGS-01 Gas Hydrate





Core photo & corresponding IR image of GH bearing sediments

The nature of sediments recovered was almost 100% clay, however, the volume of foraminifera present varied

Preliminary Results

- **Presence of hydrate confirmed at 3 of the 5 locations**
  - Layer above GHSZ, 10 to 25+ m thick
  - Disseminated in fine grained, foram-bearing to rich clay interval
  - Saturations of 20 to 40% of the pore volume
  - Gas composition was 99% methane
- **The occurrence of gas hydrate correlated well with resistivity log data at all 5 core sites**
- **There appears to be a direct relationship between resistivity and measured GH concentrations**
  - Despite relatively low resistivity values
- **There was no obvious correlation between gas hydrate occurrence and seismic data**
  - Further research on this topic is ongoing


Drs. Haiqi Zhang and Peter Schultheiss

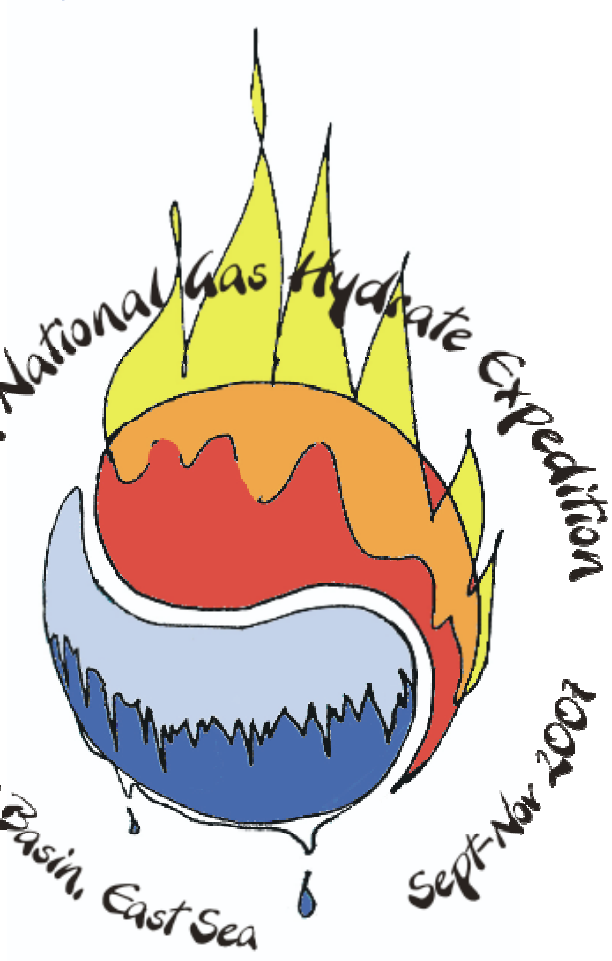

K. Rose & Dr. Zhang Guangxue

UBGH-1 Gas Hydrate Expedition

September - November, 2007

- **Principal Participants**
  - **KGHDO, KIGAM, KNOC, KOGAS**
  - **Fugro**
  - **Geotek**
  - **McGill University**
  - **NETL/DOE**

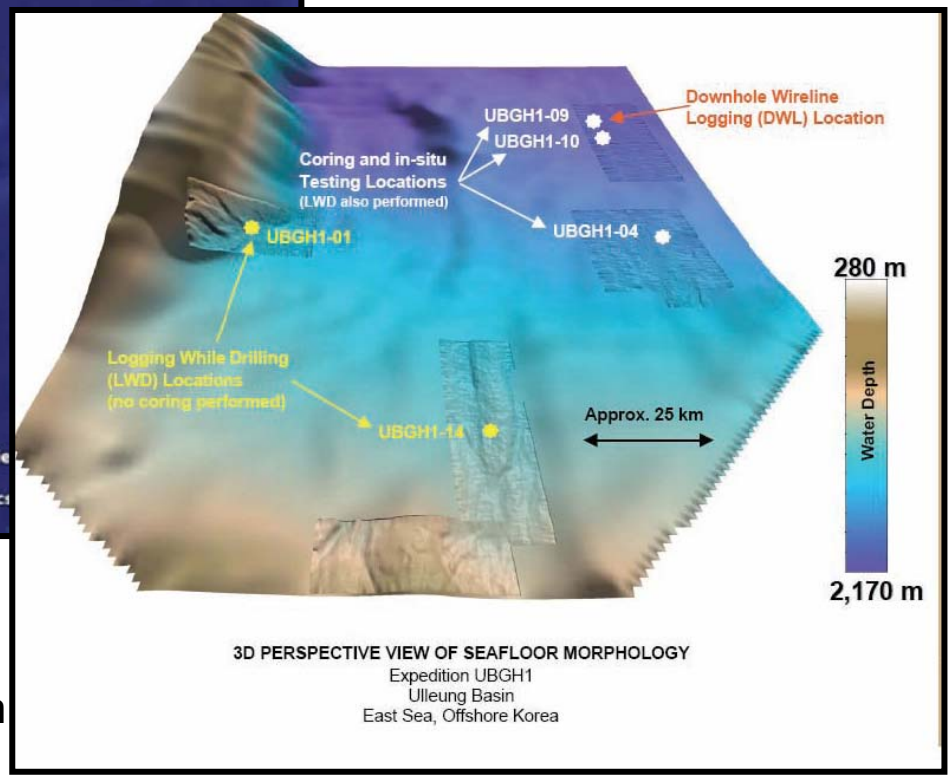
Drill ship *Rem Etive*, which had been converted to a drilling ship by Fugro Seacore using the heave compensated R100 portable drill rig



Study Area – Ulleung Basin

Three UBGH-01 Sites Cored & Sampled

- 57 days at sea
- Entailed drilling and coring at 3 sites



- Documented significant gas-hydrate bearing reservoirs up to 150 mbsf
- At water depths between 1800 to 2100m

Coring Summary

- 38 Conventional cores recovered
- 15 Pressure cores recovered
- 7 Pressure cores stored under pressure
- Conventional and pressure cores recovered using several wireline coring tools
  - The 7.5 meter, *Fugro Hydraulic Piston Corer*
  - The 3 meter, short hammer corer, *Fugro Corer*
  - The 1 meter, *Fugro Pressure Corer*
  - The 1 meter, *Fugro Rotary Pressure Corer*


Core on deck

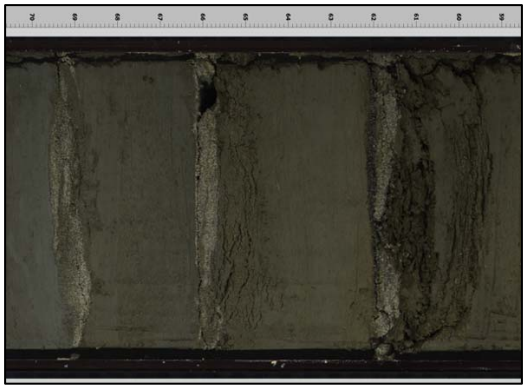

Drill floor on board REM Etive, with the FPC being loaded into the drill string prior to lowering and coring.

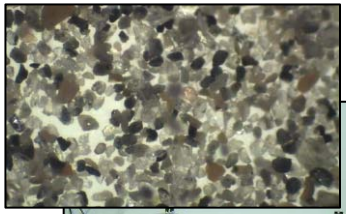
Shipboard Core Analyses

PRIMARY DEPOSITION
- Pelagic siliceous & calcareous clays
- Thin silt-sand beds
- Rare volcanic glass beds
- Volcanic glass and pumice fragments

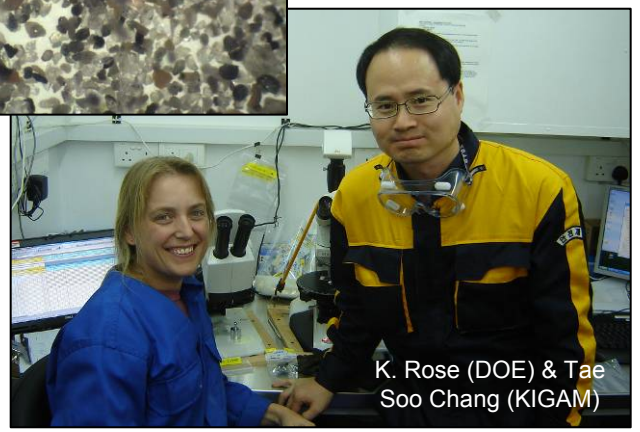
SECONDARY PRECIPITATION
- Hydrate
- Iron Sulfide mottling
- Authigenic carbonate

DEPOSITIONAL HISTORY
- Sea-level controlled slope/basin
- Turbidte/debris flows
- Periodic backarc basin, volcanic ash/glass falls





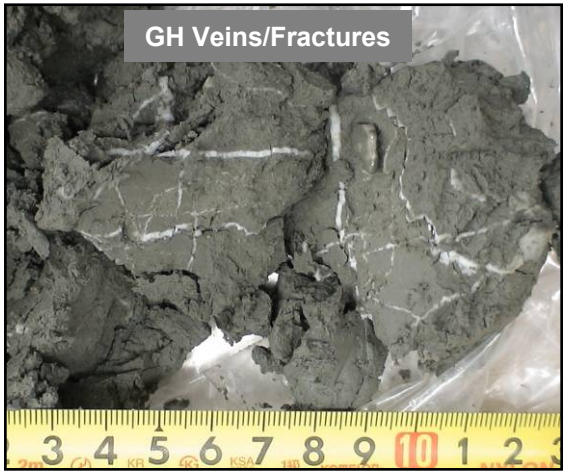
Quartz Rich Sands



Korean Science Team at Work in Lab

UBGH-01 Hydrates Samples

- Plenty of methane hydrate in various lithologies and forms
- 18 gas hydrate bearing samples preserved in LN



Back on Shore…

Dr. Schultheiss (Geotek), Dr. K.P. Park (KGHDO), & Dr. Riedel (McGill)

Ongoing incorporation of UBGH-01 results into next expedition planning

K. Rose (DOE) &
Dr. J.S. Bahk (KIGAM)

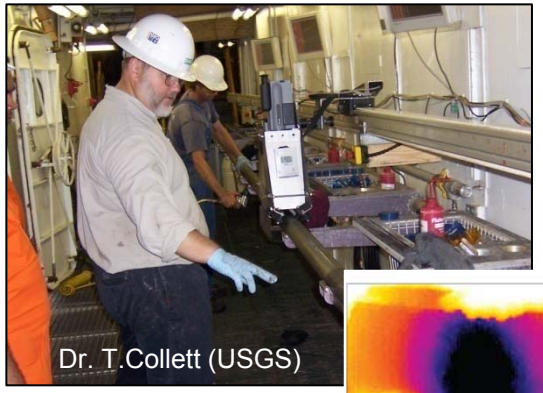
A recognized need to move beyond prospects solely based on BSRs

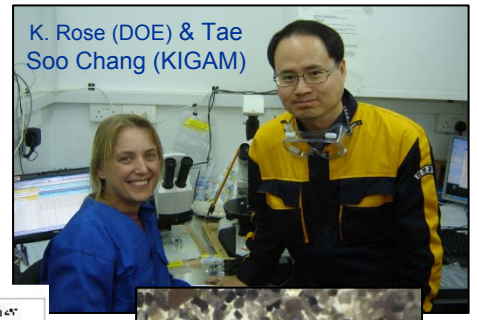
(Photo courtesy of the Korean Ministry of Commerce, Industry & Energy)

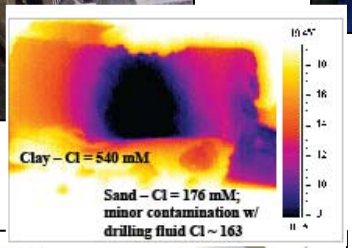
US National R&D Program

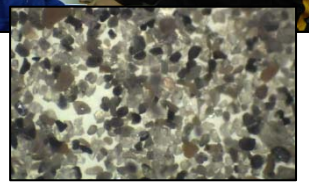
Contributing to & Benefitting from International R&D

- **Operational advances**
  - Pressure coring
  - IR and IR-geochem integration
  - Pre-core LWD
- **Science advances**
  - SMI subject to geologic complexity
  - High-saturation clay systems
  - BSRs not sufficient: Petroleum system approach needed for finding sands

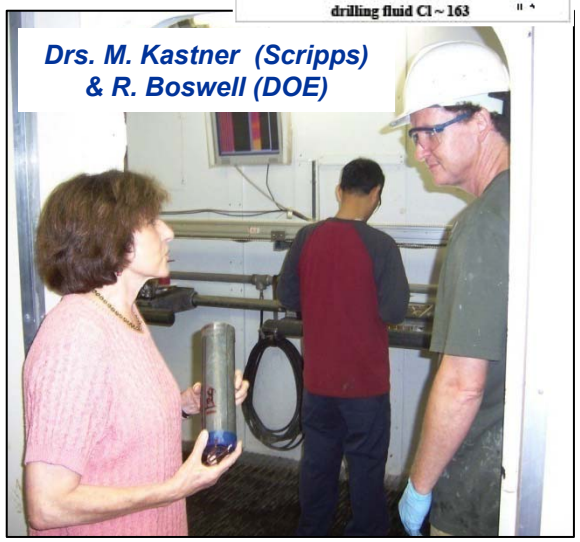




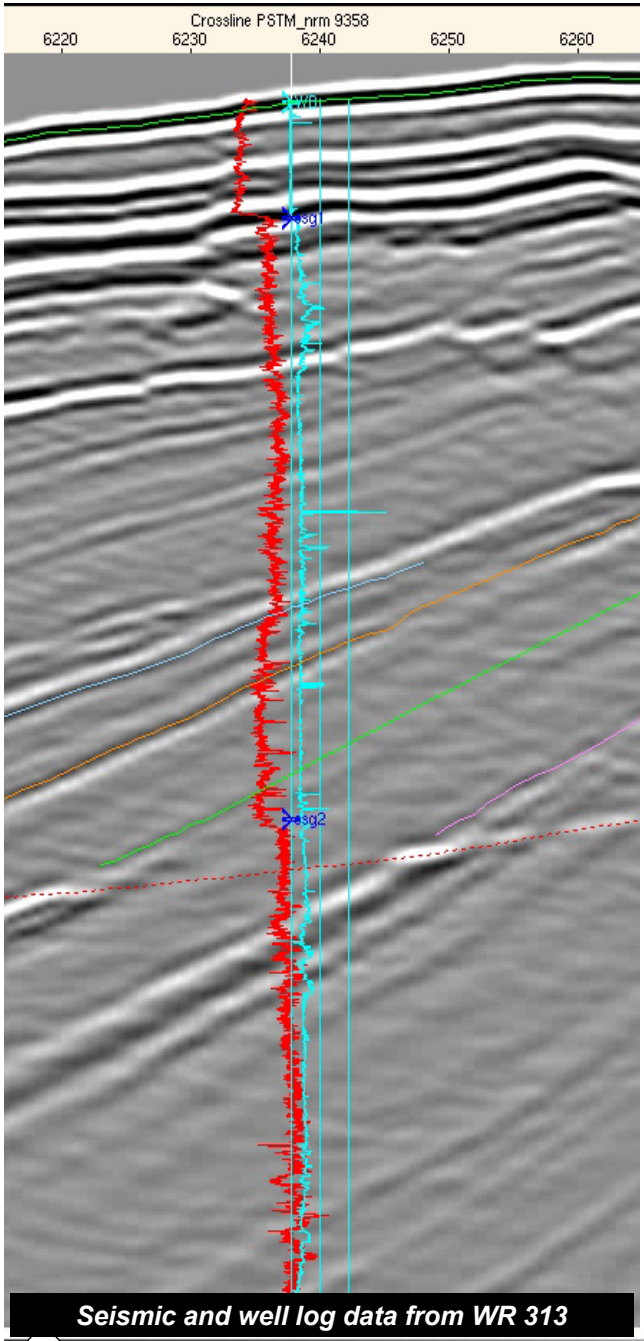




Quartz Rich Hydrate Bearing Sands



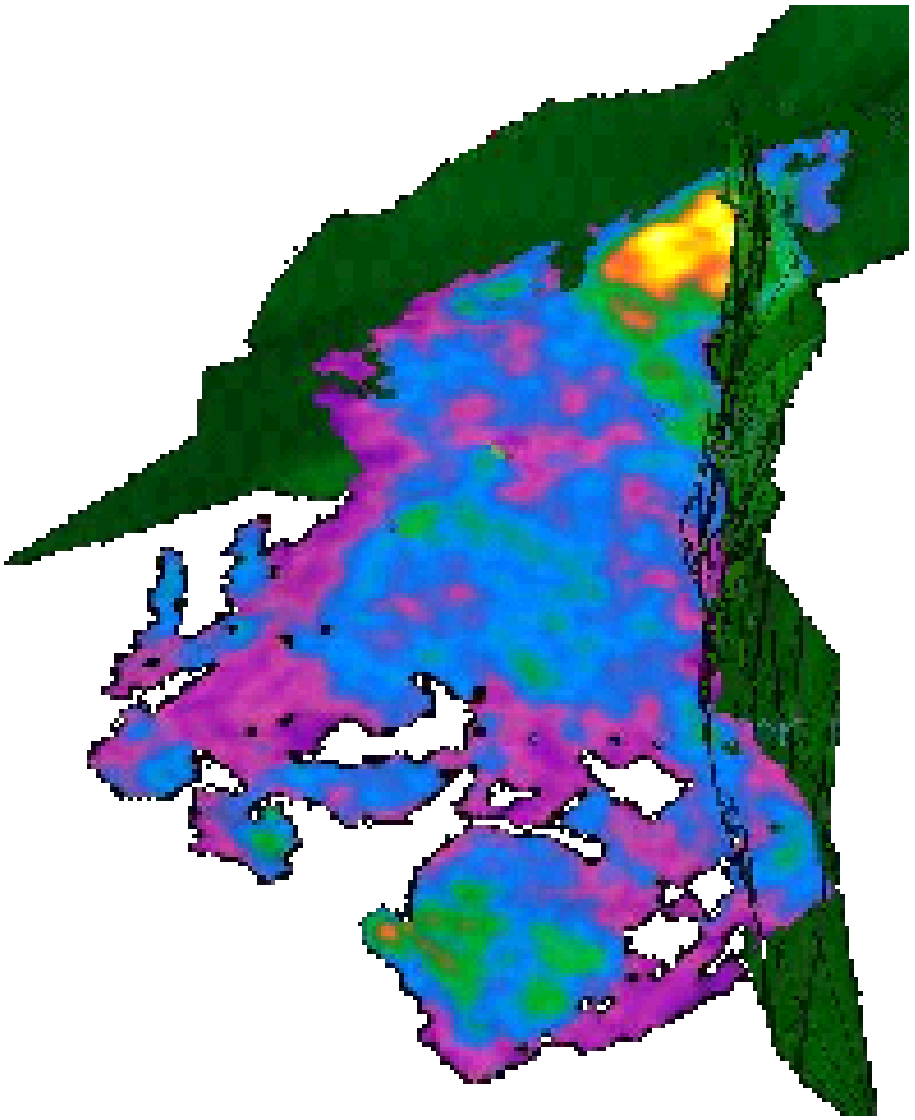
Drs. Haiqi Zhang (GMGS) and Peter Schultheiss (Geotek)



Seismic and well log data from WR 313

Presentation Outline

- The National Energy Technology Lab
- Overview of naturally-occurring gas hydrates
  - What are gas hydrates
  - Where do they occur
  - Why is there so much interest…
- The National Methane Hydrate R&D Program
- Recent major domestic & international gas hydrates field exploration efforts
- **Exploration challenges and the Program's efforts to address these key issues**
  - Basic Science: Where, why, how?
  - Resources: How much?
  - G&G: Can we find them?
  - Engineering: Can we produce them?

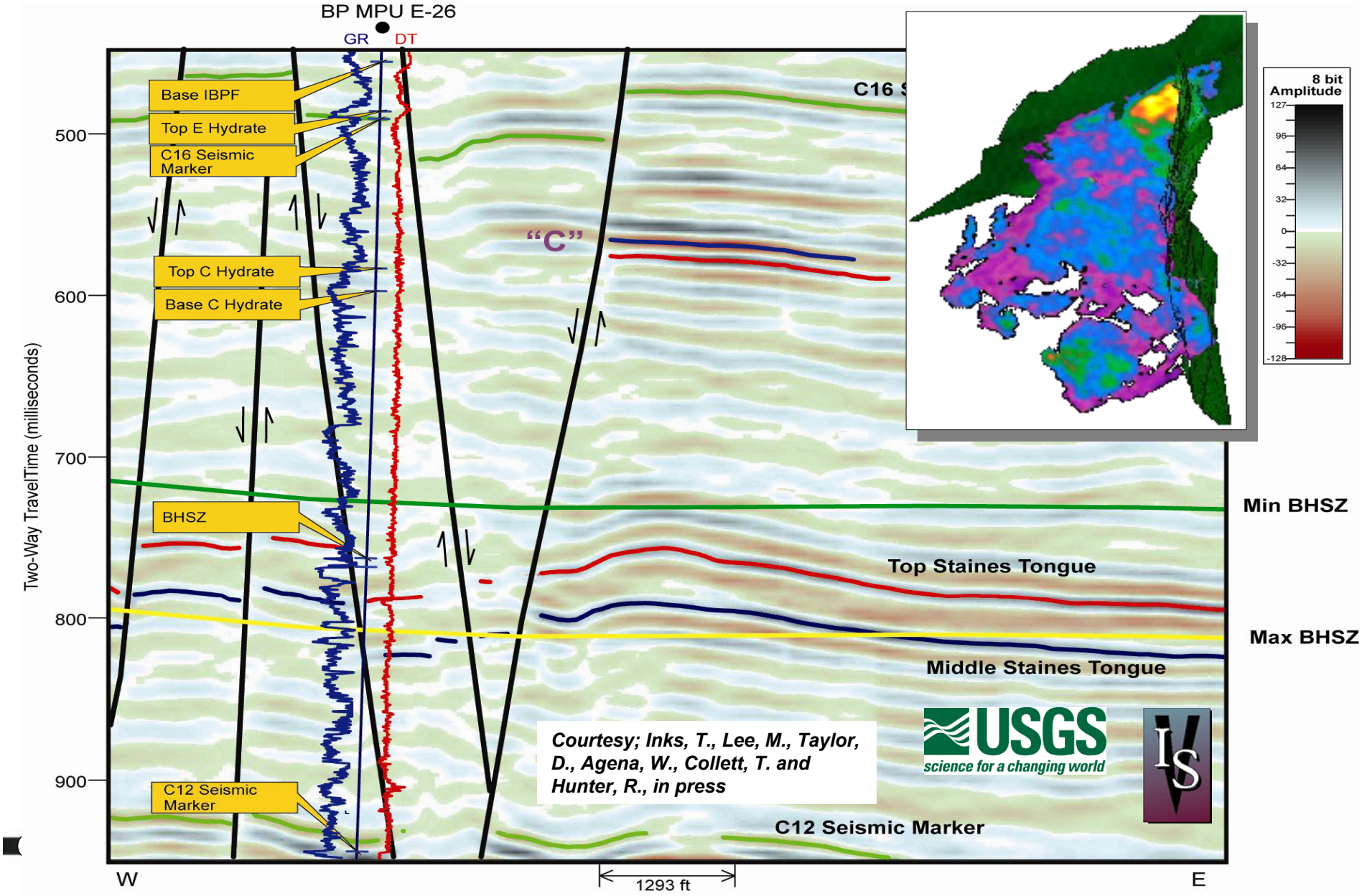


Prospect Scale Assessment

Alaska North Slope Gas Hydrates

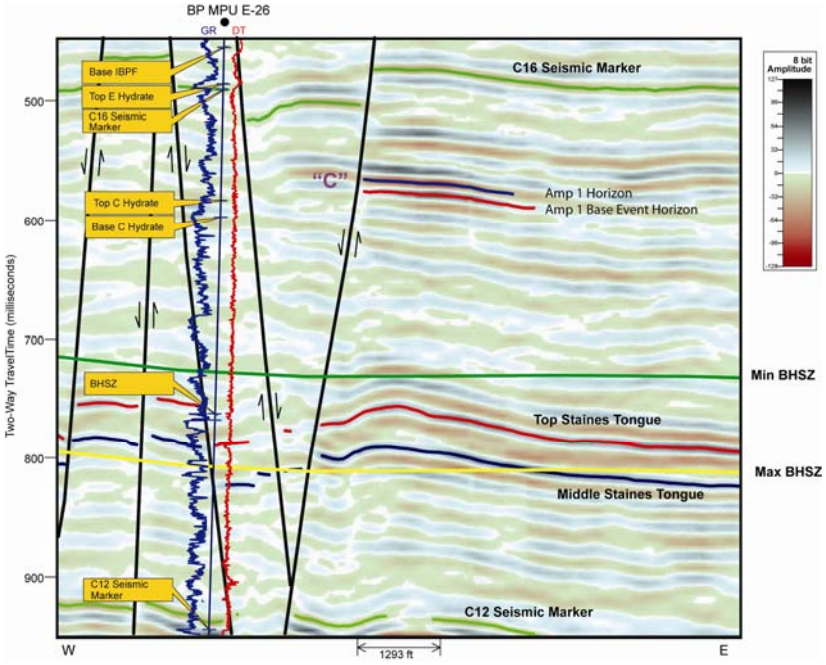
USGS
science for a changing world

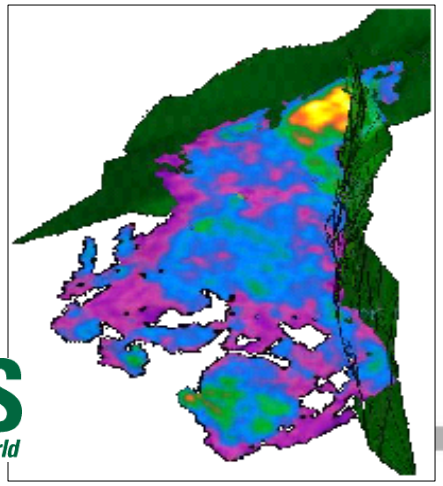
Milne Point Prospecting

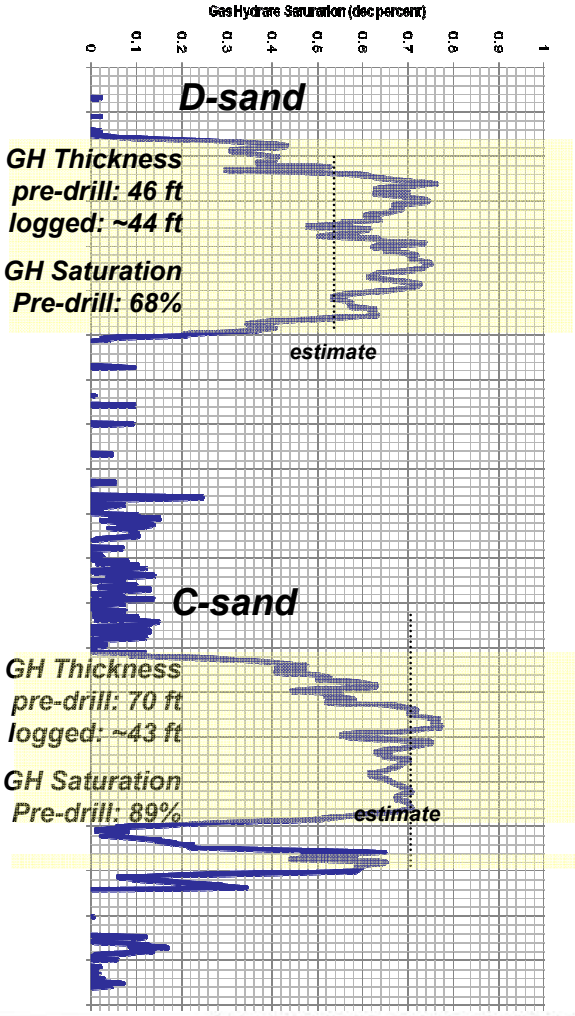


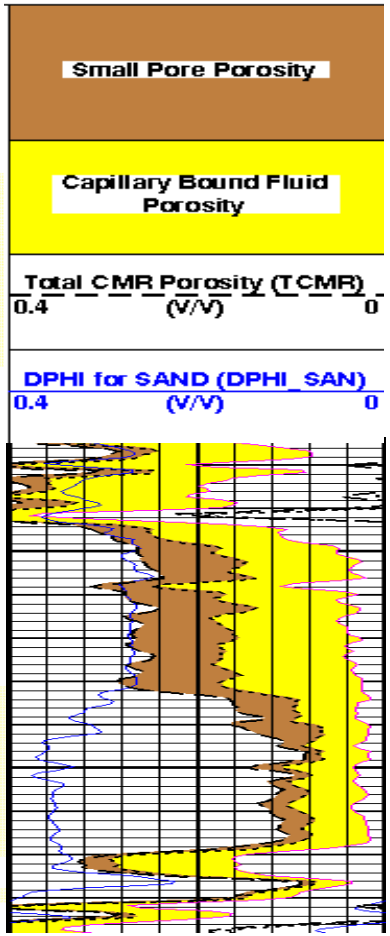
Mount Elbert #1 Well

comparison of pre-drill estimated with drilling results









USGS science for a changing world

Mount Elbert
key findings

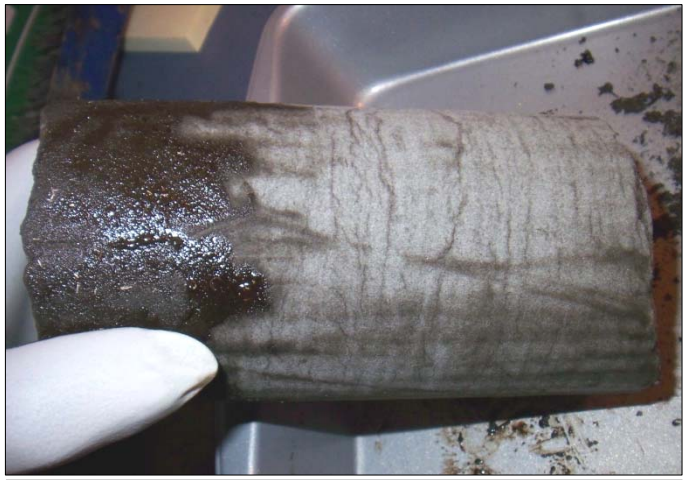
- **Confirmation of pre-drill G&G interpretation**
- **Ongoing study of core samples and details of GH occurrence:**
  - similar porosity, K, grain size of marine sands
- **Confirmation of pore fluid distribution**
  - Sgh = 65%; 25% = Swirr
  - Sgh = 75%; 10% = Swirr
- **Determination of intrinsic K**
  - 0.12 – 0.17 mD
- **Reformation kinetics important**
- **Detailed reservoir heterogeneity may control productivity**

Ice Road to Doyon-14 rig, Milne Point Alaska, February, 2007

DOE-BP-USGS Mt. Elbert Test Well

January, 2007

- Demonstrated ability to safely collect data in shallow unconsolidated sediments
- Confirmed exploration method – regional resource assessment
- First open-hole pressure test confirmed gas release and technical producibility
- Acquired the most complete dataset available to the science community
- Cost: only ~$4.2 M (Mallik = $60 M)
- Set the stage for long-term production test in FY2009?: Cost = TBD, but $25-$30m over 2 yrs – more with subsidence monitoring.



Gulf of Mexico JIP Expedition

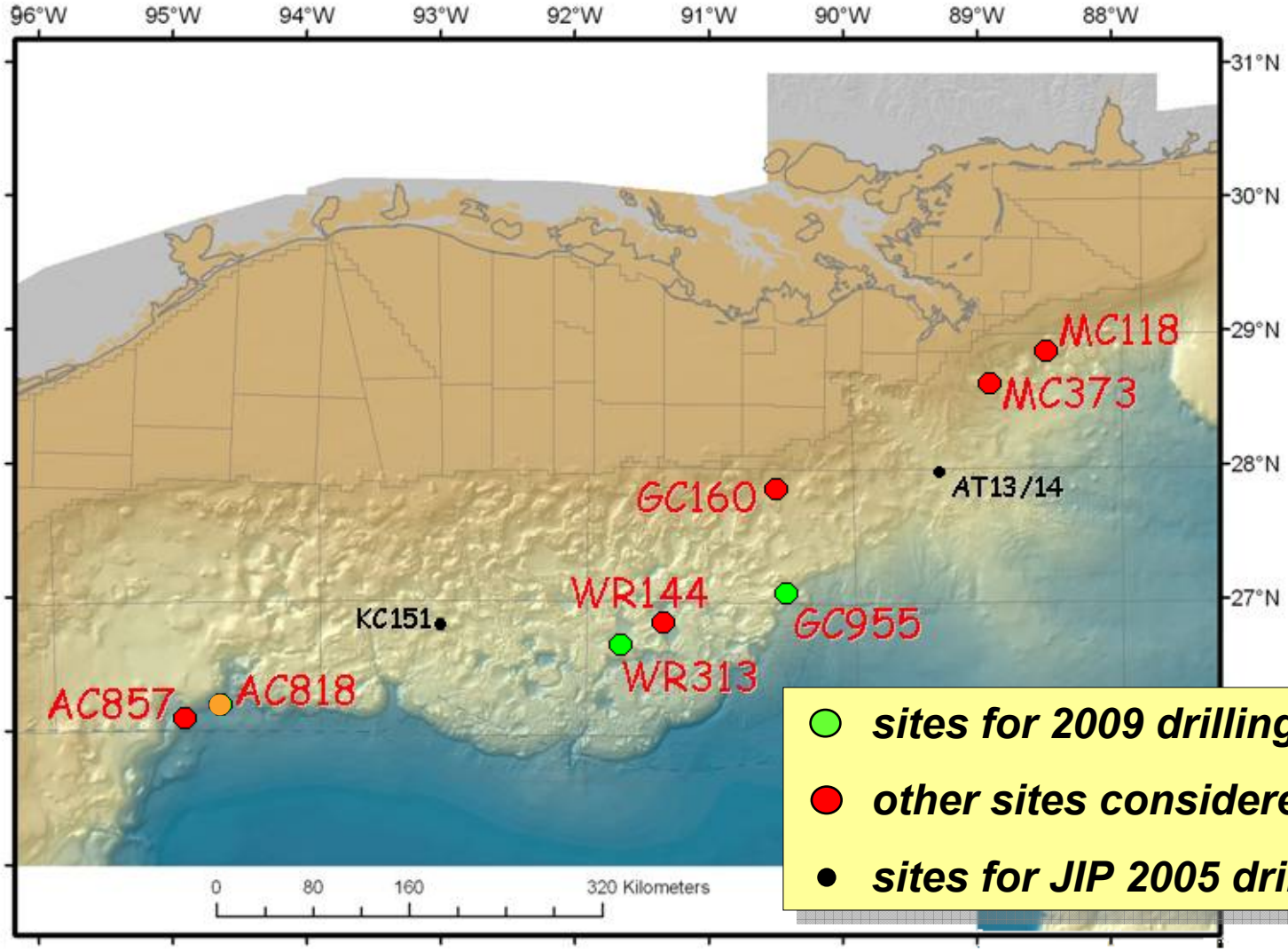
Late Spring, 2009

- **Expedition design**
  - Target sand accumulations
  - multi-site expedition w/ real-time decision-making
  - 3 sites. About 6 locations permitted per site. Likely drill 3 each
- **Objectives**
  - high-grade sites w/ LWD for subsequent coring leg,
  - further calibration of seismic techniques for GH detection
  - test alternative exploration models
  - further inform MMS GoM GH assessment

The Helix Q4000

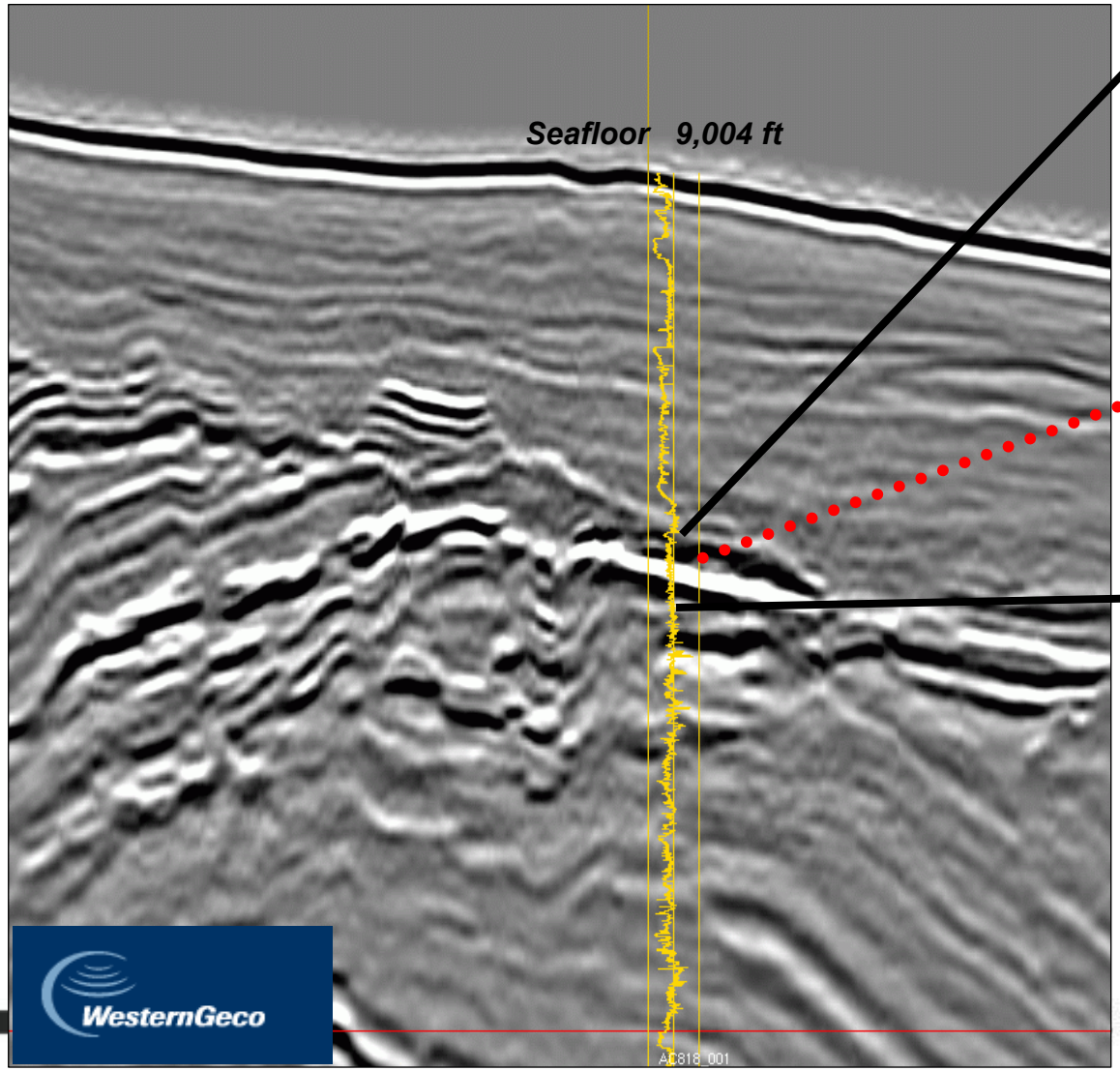
Gulf of Mexico JIP

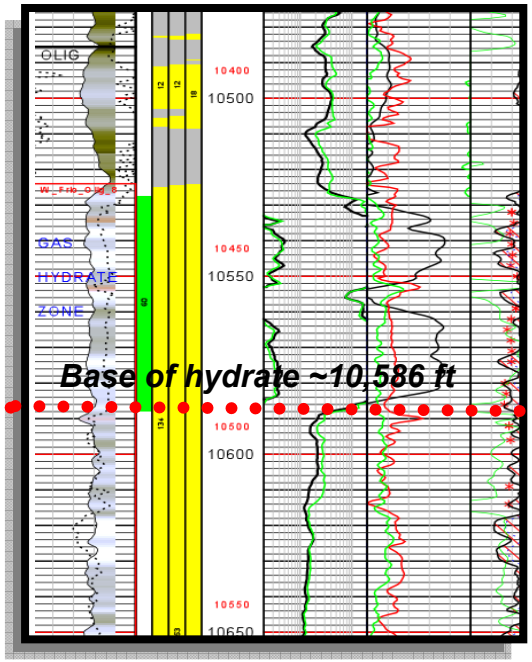
Spring 2009 LWD Program

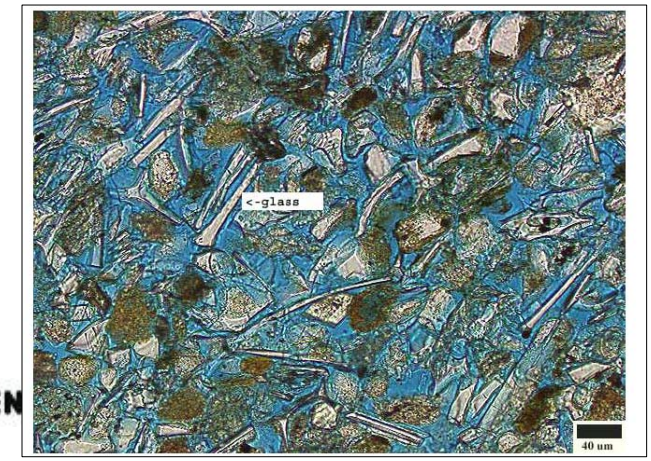


Seismic-to-log Correlation

Alaminos Canyon 818 N-S seismic line through #1 well

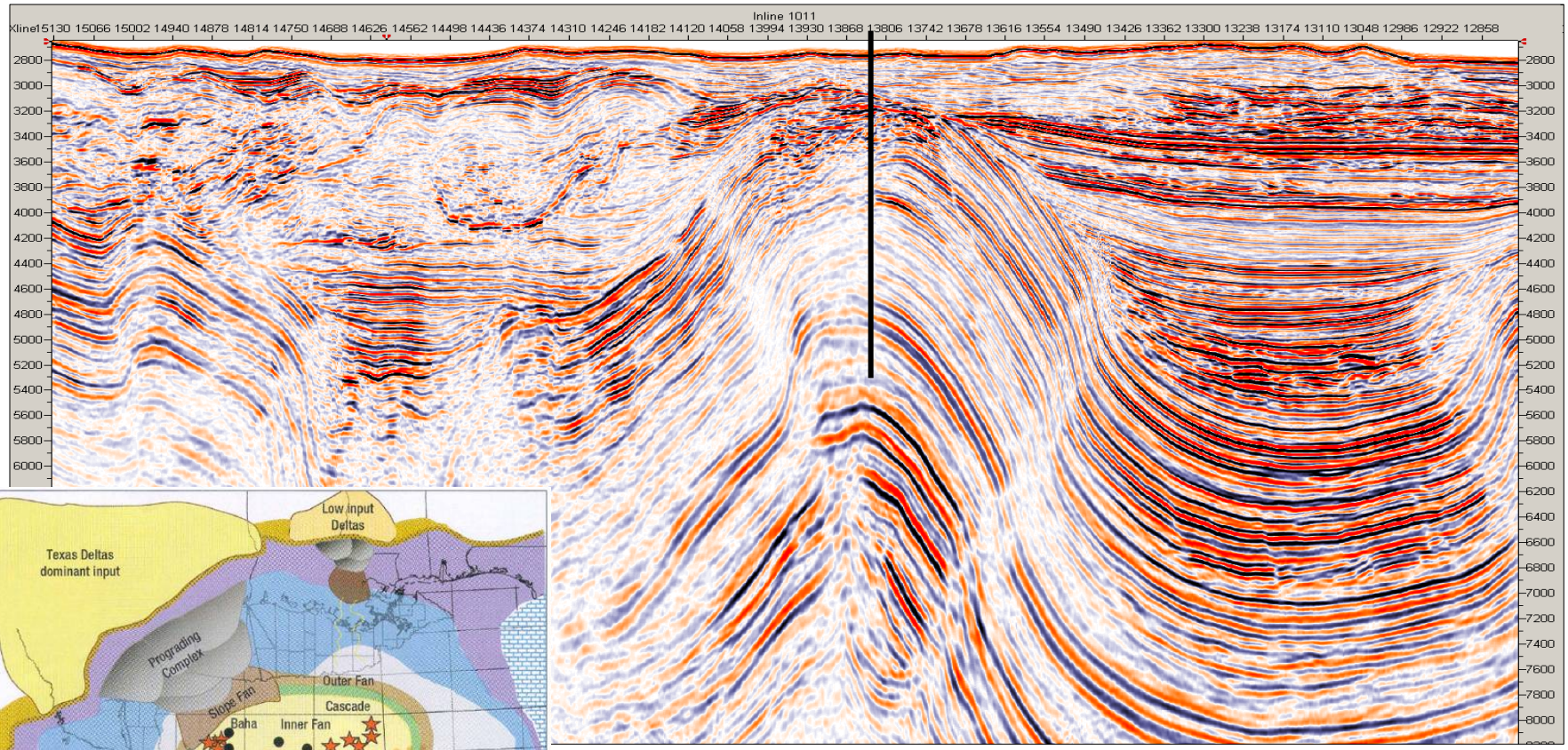


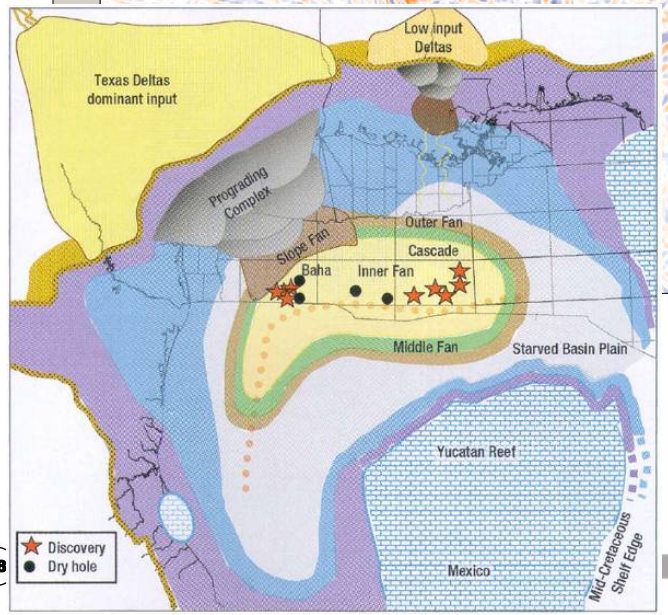




Alaminos Canyon block 818

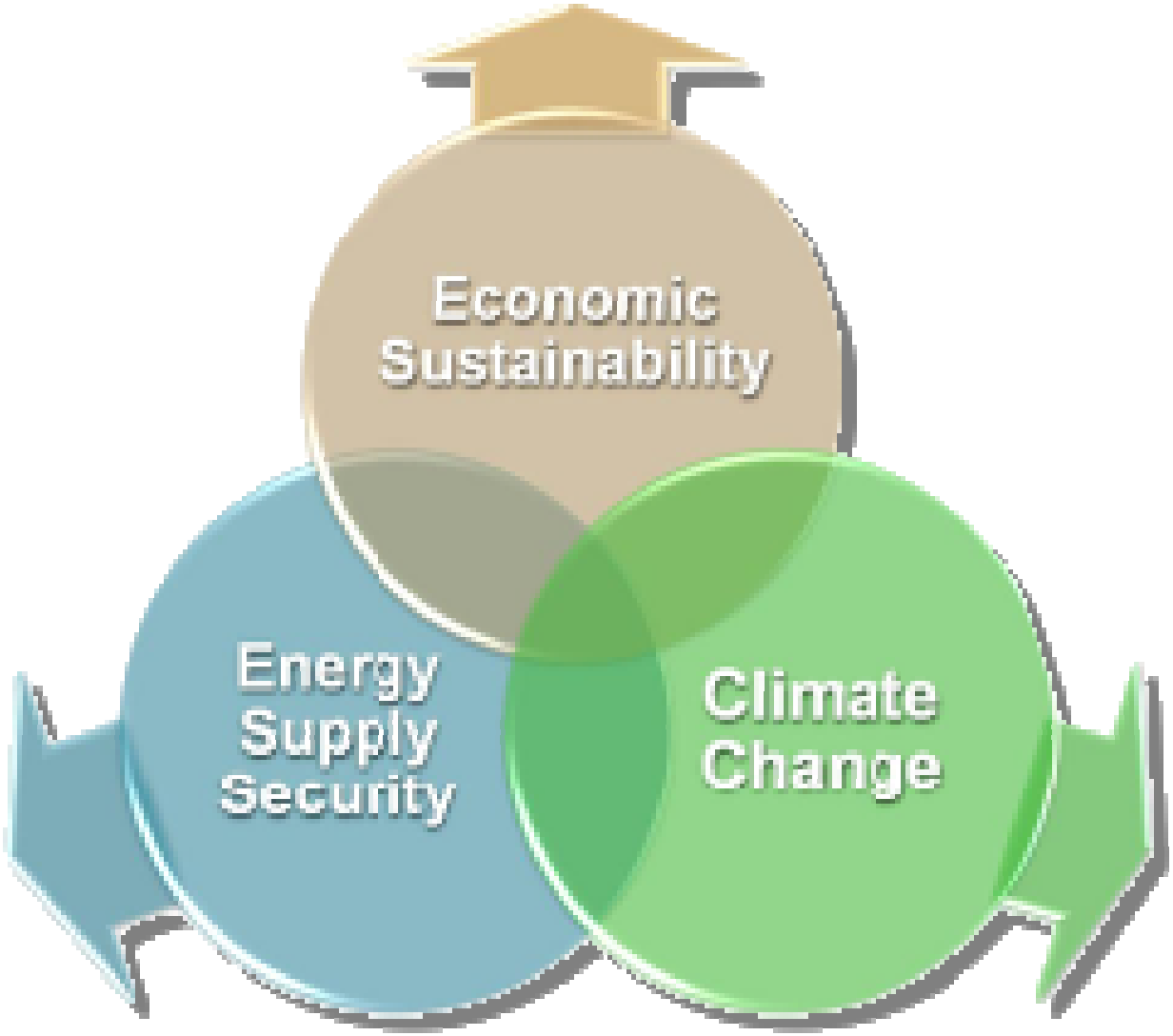
Oligocene sand uplifted by Perdido fold





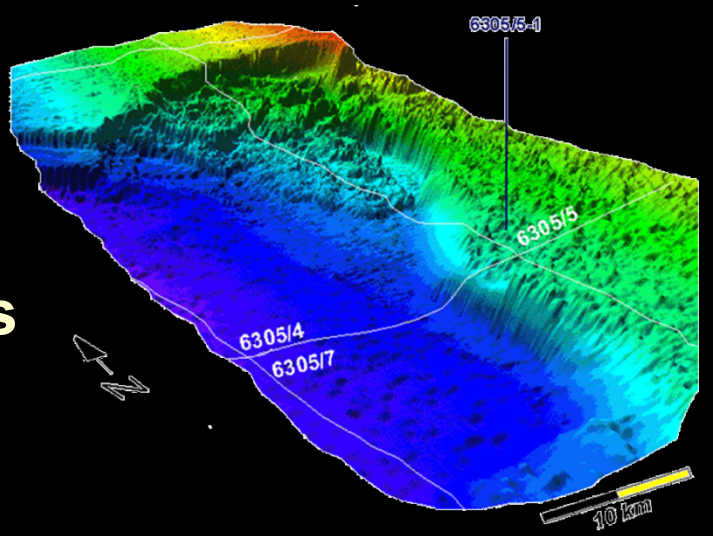
- **Greatly uplifted and well sealed – anomalous pressures**
- **Difficult and costly to drill**

Exploration advances inform…

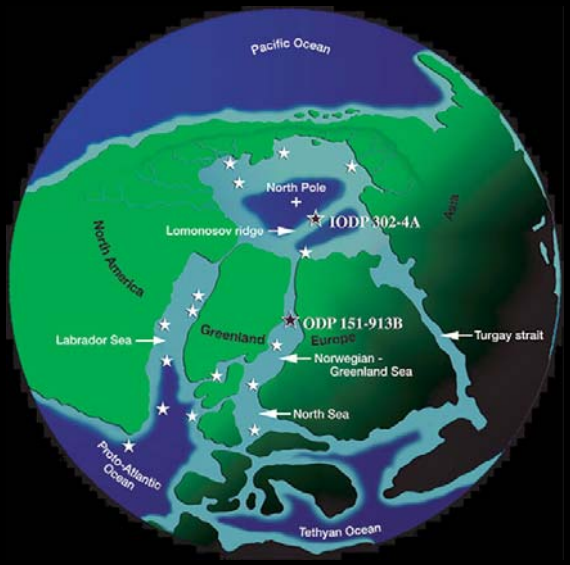


Gas Hydrates and the Global Environment

- Unique Chemosynthetic Communities



- Sea floor Failures

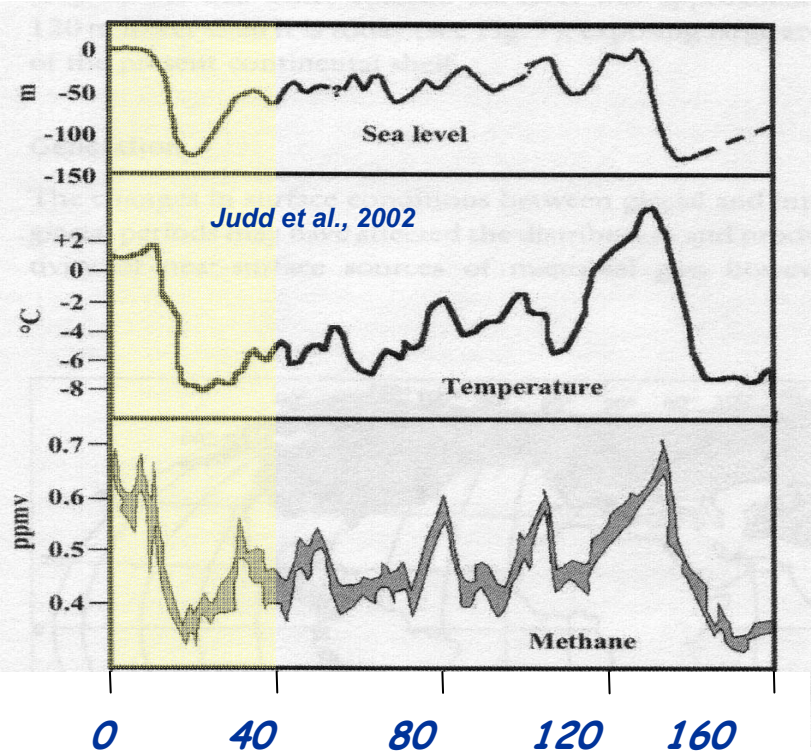


- Global Carbon Cycling and Global Climate

Environmental Aspects

Global Climate/Global Carbon Cycling

- **Sea-level, temperature, atmospheric methane content all apparently linked.**



- ***What natural process could produce periodic massive bursts of methane into the atmosphere? Hydrates? If hydrates, a driver or a follower?***

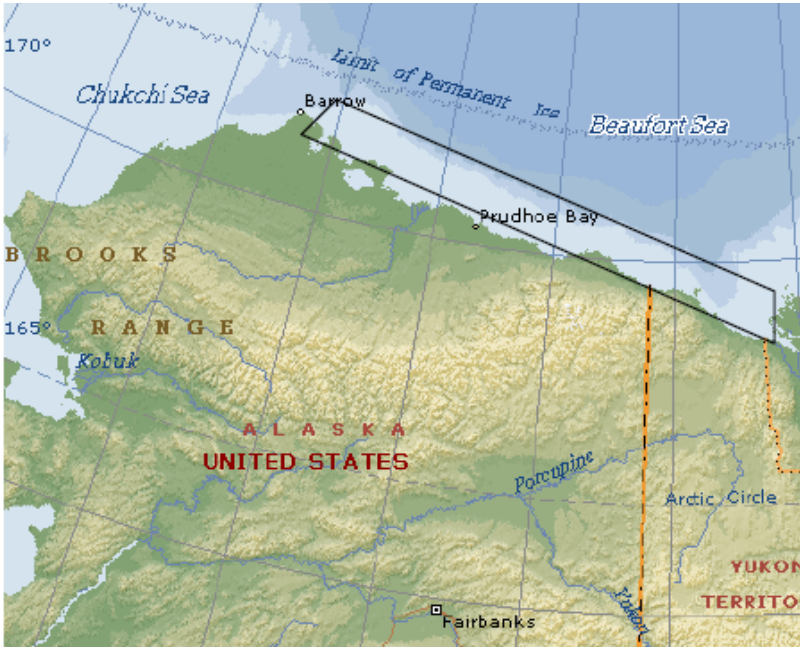
- ***Paleocene-Eocene Thermal Maximum (PETM) – perhaps a feedback mechanism?***

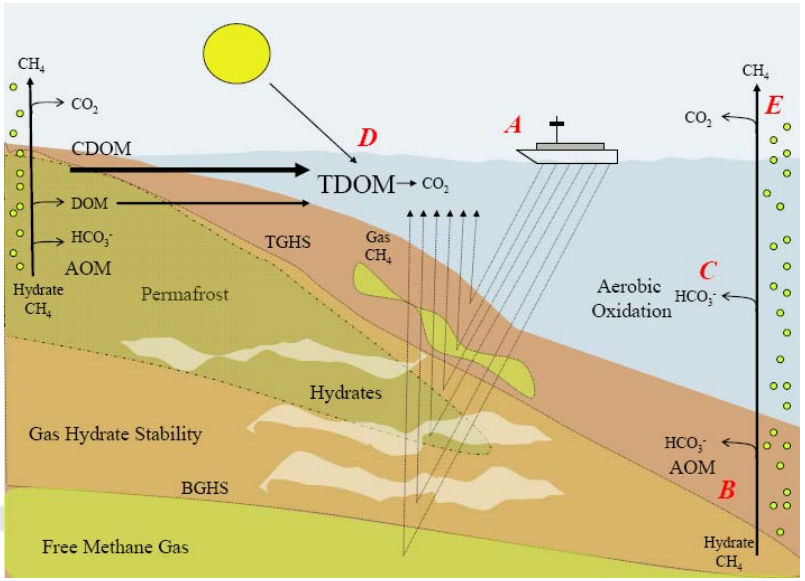
Gulf of Mexico - Ian MacDonald – Texas A&M

Submerged Permafrost & Coastal Hydrates

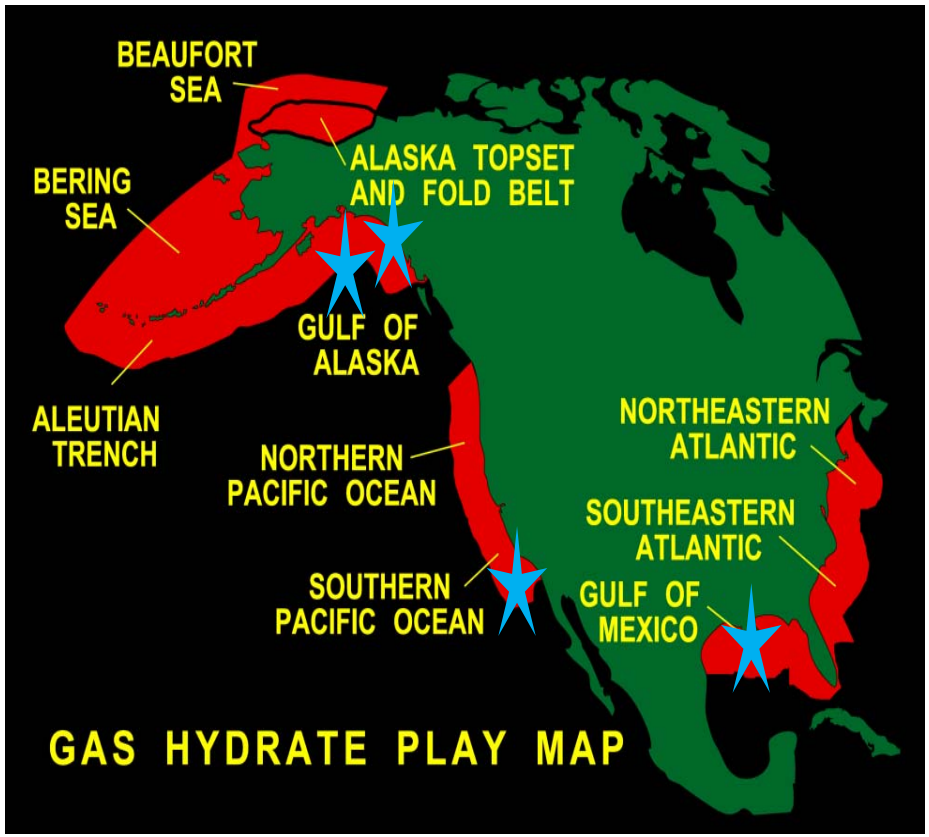
- **The Arctic Ocean is a key area for investigating the role of methane hydrates in global climate change**

- **Planned 2009 methane hydrate expedition in the Beaufort Sea**
  - NRL-led, cross disciplinary, international effort
  - Identify and characterize submerged permafrost and coastal hydrate accumulations
  - Investigate their potential role in the rate & fate of methane fluxes through the water column





Gas Hydrate – Environment and Global Climate



- Thermokarst Lakes (U. Alaska-Fairbanks and USGS)
- Gulf of Mexico CH4 flux (Texas A&M & Scripps Institute)
- Beaufort Shelf (U. Delaware)
- California Margin (U. Cal – Santa Barbara)
- Carbon input-cycling (Rice)
- Methanogenesis (OSU)
- Sea-floor hydrate solubility (FSU)
- Isotopic records of past events (WHOI)
- Reservoir response to climate change (NETL)
- Forward climate modeling (LBNL)
- Ocean biofilter (UCSB)
- Methane mobility (UT-MIT)
- GH-sediment thermal conductivity (NETL)
- Global modeling of GH response to global climate change (U. Chicago – U. Cal – Berkeley)

Cascadia Margin - 2008

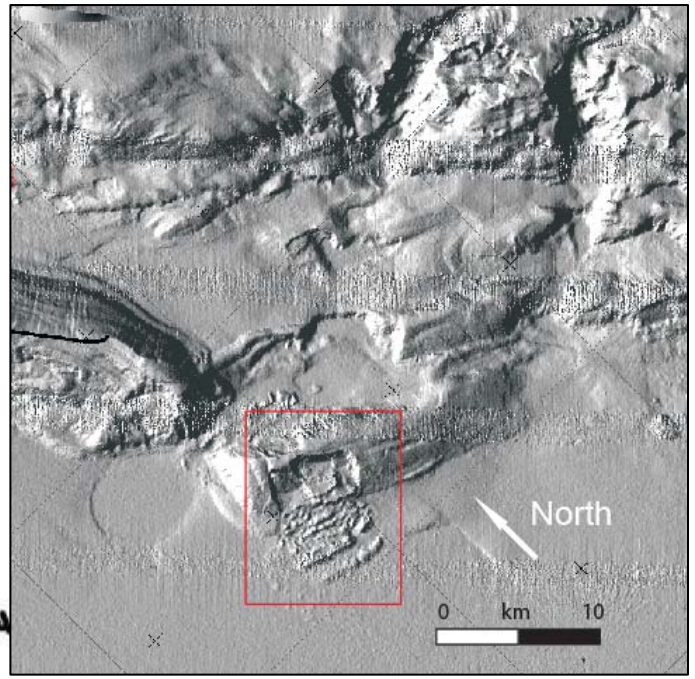
Goals of the expedition:

- Determine the timing and cause of submarine slumps at the frontal ridge
- Investigate the role of gas hydrate in the mechanisms controlling and responding to submarine slumping
- Determine the potential for fluid and gas venting and formation of gas hydrate in and around the slump sites

Science Team:

- NRcan, PGC, USGS, McGill Univ., FSU, & NETL

Processing core on the *RV Tully*
Bill Waite (USGS), Kelly Rose (NETL), John Pohlman (USGS), Michael Reidel (McGill Univ.), & Laura Lapham (FSU & NETL-NAS MH Graduate Fellow)



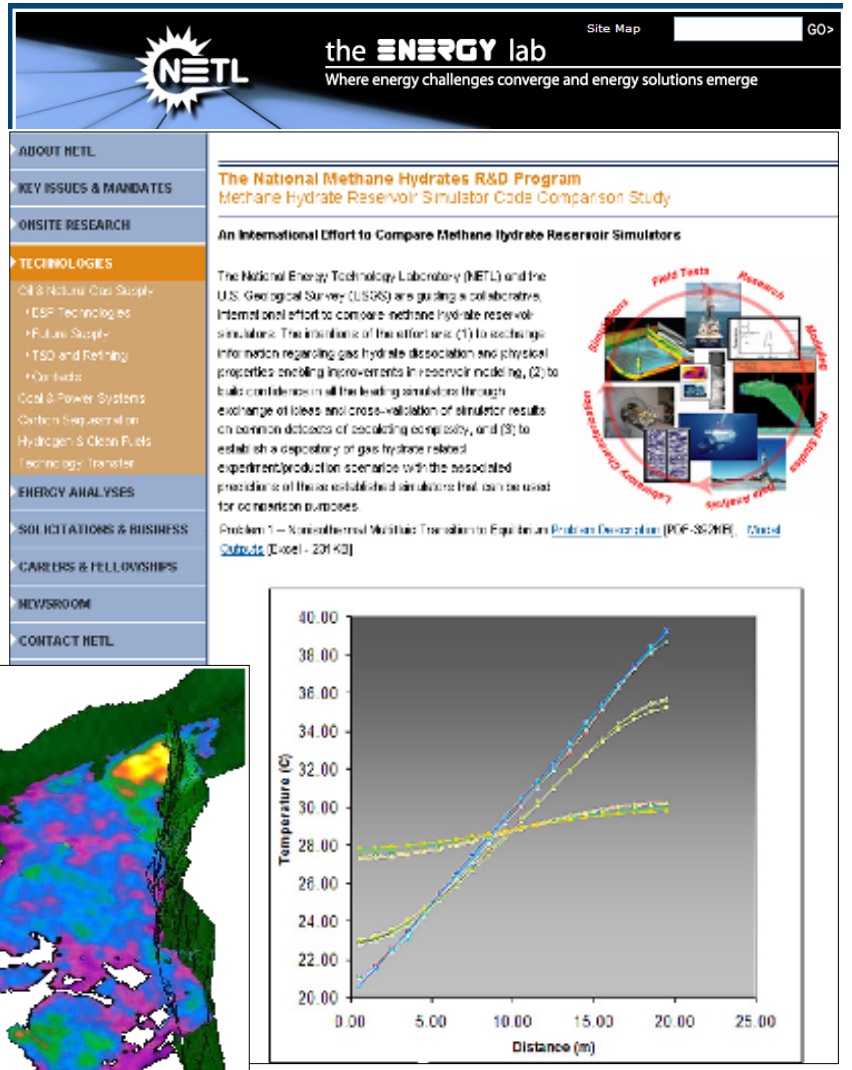
International Code Comparison Study

Of five leading gas hydrate reservoir simulators

- **International Code Comparison**
  - U.S.: (ToughFX, Stomp-HYD) LBNL, NETL, PNNL, USGS, Industry (BP)
  - Japan: (MH21)
  - Canada: (STARS)

- **All existing advanced numerical simulators**
  - Compared across common scenarios of increasing complexity

- **HydrateResSim**
  - Open-source gas hydrate reservoir simulator
  - Available through NETL website



The National Methane Hydrates Fellowship

DOE-NETL in association with NAS

- **Dedicated Fellowship Program**
  - MS/PhD/Post-Doc
  - 2 or 3 yrs/Competitive
  - Any institution (preserve student mentor relationship)
  - National Academies review
  - Interagency review
  - Selection (3/yr)

NATIONAL ACADEMY OF SCIENCES
THE NATIONAL ACADEMIES

- **Three Selections thus far**
  - ***Monica Heintz*** (UCSB) Global climate impacts
  - ***Evan Solomon*** (Scripps) Methane generation offshore India
  - ***Laura Lapham*** (FSU) New devices for measuring hydrate dissolution

Monica Heintz

Evan Solomon

Laura Lapham (right) w/ USGS and NETL scientists on recent expedition off Pacific Northwest

More Information

MH R&D Program Website

www.netl.doe.gov/methanehydrates

FITI Newsletter

The Doyon14 Rig at Milne Pt. Alaska, February 2007.

THANK YOU!!!

Kelly Rose

Geologist & Methane Hydrates Field Studies Research Lead

U.S. DOE/NETL

January 8th, 2009

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www.netl.doe.gov/methanehydrates